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THE PUBLICATION COMMITTEE

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THE DESIGN OF STORM WATER DRAINS IN A MODERN SEWER SYSTEM.

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OUTLINE.

LIST OF TABLES.

DRAWINGS ILLUSTRATING THE TEXT.

GENERAL FEATURES OF THE PROBLEM.

Hydraulic Engineering and the City Water Problem.—Broadly speaking, hydraulic engineering is the art and science of confining water. This confining is always relative rather than absolute, being an approximation toward making an unstable element stable. The city water problem consists in supplying and removing municipal water, its relative position in the hydraulic field being shown diagrammatically in Table I.

During recent years great advance has been made in the conduct of this branch of municipal affairs. Most cities now have water departments, and not a few have well-organized sewer departments. The writer believes the time not far distant when these two departments will be more widely recognized as the complements of each other, and in the more progressive communities be placed permanently in charge of trained technical men of experience and ability.

Under competent business management, such a department would be in position to benefit most largely from the advice and experience of consulting engineers, and especially would it be possible to plan definitely as to the probable future needs of a city, and then proceed with reasonable assurance of materializing such plans.

The City Water Problem and Storm Drains.—To most people, among whom may be included a large number of engineers, the sewerage problem means simply taking care of sanitary sewage, not appreciating the fact that some 99% of the flow in sewers would be foreign matter if viewed in this light. The realization that this view comprehends but half the problem has given rise to the economic demand for storm drains, which, though necessarily larger than sanitary sewers, can usually be correspondingly shorter, since natural drainage may be largely utilized.

A Three-Fold View of the Question.—Municipal hydraulic engineering deserves consideration from three points of view: the public, the taxpayer, and the engineer.

The public itself has a two-fold interest: to prevent a nuisance and to promote health. The former is by far the more potent incentive to action, although the latter is of far more vital importance; and while the danger to health from this menace has been greatly overrated, it has been even more greatly ignored. At present many of the illusions regarding disease from so-called sewer gas have been dispelled, and at the same time a thoroughly active and normal interest has been aroused regarding the need for sanitary conditions.

The taxpayer looks upon sewers and sewage disposal works as necessary evils, the construction of which is to be postponed as long as possible and then accomplished with the smallest possible outlay of cash, regardless generally of kind or quality, or of the future needs of the city. In the role of taxpayers, people are naturally obstructionists, but this point of view is largely lost sight of where the work is carried on by means of bonds or the expense is defrayed from the general treasury; therefore, when feasible, one of these methods will be found advantageous.

The city engineer too often looks upon the subject as though it were divided into three parts; house drains and fixtures to be left in the hands of plumbers and inspectors, catch basins and the like to be constructed from standard plans on file in his office, large sewers and disposal works to be constructed after consultation with a specialist. The fact is that the specialist should be consulted regarding the entire system, otherwise how can the different parts be expected to form a complete whole? The natural desire of the engineer is to eliminate the first two points of view, substituting his judgment instead. It is well to bear in mind, however, that they have to be reckoned with, for the possibility of planning and completing a satisfactory system depends almost entirely on their relative ascendency and influence.

Essentials of a Good System.—Until recent years, and still very largely, sewer systems were constructed haphazard and piecemeal, resulting in inefficiency and unnecessary cost. This can be obviated only by having a comprehensive plan to serve as guide in the design and construction of all sewers.

This plan should not only be comprehensive, but should be worked out in detail to a far greater degree than is generally assumed. By the very nature of things it will be many years in building, and, in fact, will never be entirely finished. This emphasizes the need for an early and rational determination of as many factors as possible, in order to best care for the present and future generations. No system would be considered modern which did not accommodate every building lot for sanitary purposes and supplement all gutters for storm runoff. This does not mean that storm drains should run to summits like sanitary sewers; on the contrary, it is usually advisable to allow storm water to flow in the gutters for an entire block or more. The first street inlet, and

consequent beginning of the sewer, should be placed as far from the summit as can be done without allowing the depth of water in the gutter to become a nuisance during heavy rains. This results in a considerable saving of money and is in accord with the accepted principle that storm drains are designed to supplement, not to replace gutters.

Another requisite is that sewers shall be constructed watertight. If it were not for glaring defects of this nature in nearly every city of the land, such a statement would be considered self-evident. The need is especially urgent in sanitary sewers. On the other hand, if there were any great advantage in doing so, storm drains might be constructed with a view to allowing slight infiltration whenever the water table was above them, since at times when it was below there would be but slight objection if water did leak out, especially during the short period of a storm. This would enable them to act as drains in the true sense of the word, keeping the permanent water plane near the level of their invert. The chief objection to this is the additional depth and cost resulting in building them below the levels of cellars. The better way is to lay small drain tile for this purpose, directly below the storm drains, wherever local conditions require the draining of the land.

The question of allowable velocities is not well understood, in spite of the fact that engineers have had to deal with it for centuries. Economy in construction requires that velocities be limited by only two things—the general slope of the surface and possible erosion of the invert. The writer is of the opinion that danger to the latter has been greatly overrated, and is conducting a series of studies at the present time with regard to maximum limits of velocity in hydraulic work. The probability is that 20 ft. per sec. over a good concrete surface is perfectly feasible. With good concrete construction there is very little danger of the invert cutting out. On the other hand, the velocity must not be so low that the cost of attendance, in the way of cleaning and flushing, is unwarrantably high. In the case of flat and low-lying territory, like New Orleans for example, this is sometimes overcome by occasional pumping stations. Present opinion favors a minimum velocity of 20 in. per sec. during the lowest stages of sanitary sewers. A rule adopted by the writer is to allow 3 ft. per sec. when the sewer is half full, which accomplishes practically the same result and is readily applied when using tables or diagrams.

Every one recognizes that capacity is a vital consideration; but while it is of prime importance that sewers be adequate for present needs and future growth, it is not so generally recognized that if they are made unnecessarily large they will be less satisfactory owing to low velocities and high cost of maintenance. This is especially true during the period of years elapsing while the territory served is being built up. It is seldom feasible, as is so often done in the case of water supply mains, to supplement sewers

by constructing parallel ones some years later. For this reason it is evident that the planning of a system to remove the water from a municipality becomes urgent much earlier than comprehensive plans for its supply.

Another essential is that the system be designed so as to minimize hand labor, cleaning the sewers as largely as possible by means of flushing with water. It is very desirable also that the flushing be by means of automatic flush tanks discharging at regular intervals, special occasions only being taken care of by using the hose. It requires a large amount of water, even when purchased at a high rate from a private company, to equal the cost of inefficient day labor in the cleaning of sewers.

As a final thought, there are two tests which may be applied in forming a judgment concerning a sewer system: that it shall promote public health and prevent a nuisance, and that the first cost shall be as low as consistent with minimum maintenance charges.

Disposing of Sewage.—It is usually held as a desideratum that disposal works be located to one side and at some distance from a city,—the farther the better. This last is true provided the added cost of construction and maintenance be balanced against any possible nuisance which may be caused in the proximity of the works, with consequent deterioration of property values. It by no means follows that all of the sewage should be disposed of at one point, or even by the same method and to the same extent.

A popular misconception is that the proper disposition of sewage presupposes extensive and elaborate appliances; the fact being that it varies all the way from merely an outfall sewer into a stream of water requiring no attention whatever, to a complicated system of settling basins, septic tanks, filters and sludge disposal appliances, requiring a considerable force of skilled and common labor under the direction of scientific experts. The prime requisites are that it be efficient, simple, and economical.

The Separate or Combined System.—After careful study has been made of the available methods of sewage disposal, it is then possible to logically consider the relative merits of the separate and the combined systems. This is seldom a problem as such, usually resolving itself into supplementing a combined system in the older parts of the city, and in the newer and unsewered portions using the one or the other, depending on local conditions, or frequently a judicious combination of the two.

In addition to meeting natural conditions, these conclusions must largely satisfy the public point of view, or rather one's judgment as to what that view is and is likely to become; and then comparing cost estimates of various tentative plans until a system is developed which may be built at as low a figure as is compatible with permanency and adequateness.

Estimating the Amount of Sewage.—To the lay mind, sewage is sewage wherever found; yet the composition of sewage in

America is noticeably unlike that of Europe, a marked difference appearing even in the cities of this country. This difference comes largely in the amount of dilution and in the relative proportions of sanitary sewage, trade wastes, and storm water runoff. Only the latter will be considered in this paper.

The amount of storm water for which allowance should be made is generally determined by the application of some one of the well-known formulas, such as the McMath, Hering, Burtli-Ziegler, Parmley, Gregory, and others. A very elaborate determination has lately been made by Mr. C. E. Grunsky, member of the American Society of Civil Engineers, in his studies regarding "The Sewer System of San Francisco and a Solution of the Storm Water Flow Problem". One much easier of application, although not comparable in its analytic grasp of the subject, has been proposed by Mr. Carl H. Nordell, Bureau of Sewers, Borough of Queens, New York City. A method having somewhat similar features, and comprehensive in its treatment, has been developed by the writer and is being applied in the work at Kansas City.

Whatever method is followed, it is necessary to assume some maximum precipitation for which the system will be designed. Then, from local conditions, estimate the runoff to be cared for by the different sewers.

NECESSARY ASSUMPTIONS AND APPROXIMATIONS.

Typical Sewer Lengths.—By sewer length, in this connection, is meant the time required for water to flow through it, not its length in feet. Deciding upon typical lengths is a matter of judgment for each city, sometimes requiring to be changed in different portions of the same city.

Where the grades are fairly steep, as in Pittsburg, Kansas City, and other places similarly situated, time intervals for main, branch, and lateral sewers may be tentatively assumed at 40, 20, and 10 minutes respectively. In Chicago, New Orleans, and other cities having practically level streets, the periods may easily be 60, 30, and 15 minutes, or in extreme cases 2 hours, 1 hour, and ½ hour, unless there were outlets like the Chicago River, Lake Michigan, and Lake Pontchartrain, making the sewers very short. These cases are merely suggestive, and each city must be considered on its merits; in some cases two typical lengths will suffice, while in others four may be required. These time periods depend on both the absolute and relative length of the different sewers, as well as on the general shape of a city's typical rain curves.

A rigidly rational method would consider each sewer as an entity, treating it as though it were the only storm drain in the city. This would mean determining the time of surface concentration, the perviousness of the surface, the frequency with which it would be permissible to flood it, a precipitation curve suited to its individual characteristics, and by means of trial solutions its actual

time length; all of which would be manifestly impossible with the funds available for such work. There is grave question whether the present state of our knowledge would warrant such elaborate treatment, even if taxpayers were willing to pay for it.

On the other hand, a number of engineers have developed formulas with the hope of obviating many of the above difficulties. It is now pretty generally admitted that no arrangement of coefficients is possible, which shall take into account all of the varying conditions and at the same time be sufficiently simple in its application; at least, that such efforts can be only a partial success until much more data have been secured from which deductions may be made.

There would seem to be room, however, for rational effort somewhere between these two extremes of treating a city's sewers as though they were all different or else all alike, and it is this middle ground which the writer has attempted to occupy. To lessen the work which would necessarily result if each sewer were treated independently, typical sewer lengths have been adopted; and to make certain of developing really typical rain curves, the question has been met squarely by deciding on definite surcharge periods, thus setting time limits when a city can better afford to have a sewer flooded than to pay for a larger one.

Surcharge Periods.—It is readily conceded that most cities cannot afford to build storm drains to care for their heaviest precipitations. If this were attempted, Columbus, Ohio, would build for about 4 inches of rainfall, St. Louis and Milwaukee each for 5 inches, while Kansas City has experienced a rate of over 7 inches per hour, the average for 40 minutes being nearly 6 inches. As averages for 10, 20, and 40 minutes, the rates given in Table II, were reached during the past 10 years by the cities mentioned.

It is worth noting in the table that if one were designing for the Shreveport rains there would probably be no need for typical sewer lengths, as its intensity varied less than 5%, whether considered for a period of 10 or of 40 minutes duration. Those at Kansas City and Topeka come next with a variation of about 15%, while the one at St. Louis varies nearly 40%.

Whatever method is used in computing the required carrying capacity of the sewers, it is necessary either directly or indirectly to decide how frequently a city can afford to have its storm drains flooded rather than to build them larger, and by so doing further increase its burden of debt and expenditure. This is a matter requiring greater judgment than any other confronting the engineer engaged in storm drain design.

As a question of economics, it resolves itself into the total loss caused by flooding streets and cellars to a greater or less extent, set over against the interest on such additional expenditure as would have prevented the flooding. In this connection it is well

to remember that the loss considered must cover both the damage to property and the inconvenience which results.

As just indicated, the most careful thought should be given this phase of the subject. Each city will necessarily work out its own surcharge periods, depending on the shape of its rain curves, its financial ability, and the attitude of the people toward mortgaging the future.

In Kansas City it has been decided to design main sewers with the expectation of flooding every 10 years, branch sewers every 5 years, and laterals every 2 years. At first thought this seems too frequent in the case of laterals, but when it is borne in mind that they must be designed for 10 minute precipitations, and so must be much larger proportionally than either branch or main sewers, and that flooding in their case means simply carrying the water somewhat further in the gutters, it is readily perceived that true economy is served by making the time interval short.

Permeability of Surface.—It is now universally conceded that the perviousness of areas is only second in importance to the rate of precipitation, as a controlling factor in storm water runoff; since the runoff equals the precipitation less the perviousness.

The writer believes it preferable to estimate perviousness as depth in inches per hour which a given surface will absorb, rather than a given percentage of the rainfall, since there is little difference in the rate of absorption whether the rainfall be light or heavy, so long as the intensity of the downpour equals or exceeds the rate at which the surface is capable of absorbing it.

Perviousness depends on the kind and depth both of the surface soil and the sub-soil, and whether the surface is barren, covered with grass, or paved. Paved areas are usually considered impervious, but are only relatively so. This is demonstrated by the fact that the runoff from so-called impervious areas never equals the total precipitation.

In all probability the curve of perviousness is never a straight line; however, as a working basis, to be corrected later by the results of gaging, it has been assumed in Kansas City that paved surfaces absorb water at the rate of 0.50 in. per hour at the beginning of a storm, decreasing to 0.25 at the end of 15 minutes, and to 0.00 at the end of 60 minutes; that lawns and other grass surfaces absorb 0.75 in. at the beginning, decreasing to 0.50 at the end of 30 minutes, and to 0.00 at the end of 120 minutes; that garden and other barren soils absorb 1.00 in. at the beginning, decreasing to 0.75 at the end of 30 minutes, and to 0.00 at the expiration of 120 minutes. This is shown graphically in Fig. 3.

Surface Concentration.—The time required for surface concentration depends on the distance to catch basins and the mean slope of the surface. In calculations involving this time, the velocity of flow at Kansas City was assumed, from the meager data available, to be 100 ft. per min. for an unpaved surface having a slope

of 5 ft. to the hundred; other slopes being in proportion. Paved surfaces were assumed at twice the velocity.

The type of runoff tract used is 330 x 660 ft., being a standard city block. With this as a basis, three typical areas were worked out as follows: Type I, having 20% of paved surface and two-thirds of the remainder barren. Type II, 50% paved and equal portions of barren and lawn surface. Type III, 80% paved and one-third of the remainder barren.

These are proving satisfactory for study purposes and tentative designs. They give one, two, and three blocks as the respective distances which require 5 minutes, where the slope is 5%.

A RATIONAL SOLUTION.

Rainfall Data.—There can be no doubt that more grave errors in storm drain design have been due to lack of reliable and complete

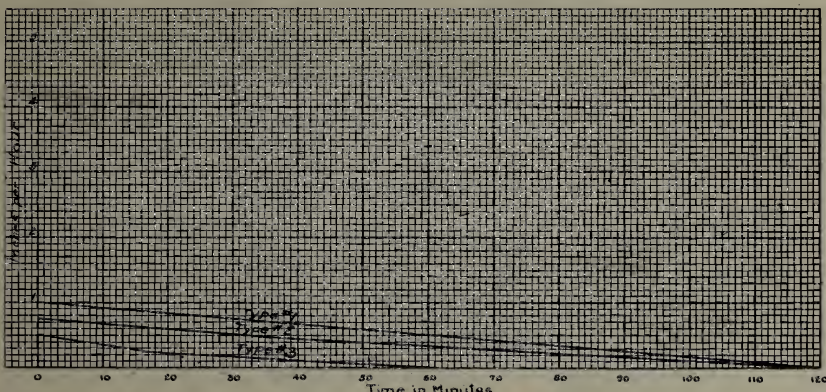

FIG. 3 · CURVES OF PERVIOUSNESS

information than to all other causes combined. This realization led the writer, during the preliminary studies in Kansas City, to devote much time and thought to gathering and compiling exhaustive rainfall data.

Since automatic records have been kept for but little more than a decade, the records from a single city are insufficient for reliable work, so data have been gathered and tabulated from the entire watershed of the Mississippi River, as shown in Fig. 1. All weather bureaus having automatic records extending over a period of 5 years or more have contributed their heavier precipitations, and the information here presented is believed to be both reliable and complete.

A careful study of the question has led the writer to conclude that for ranking rains in the order of their intensities, the method of average precipitation is at once simple and adequate, therefore satisfactory. This method has been used in preparing the following

tables. They were computed for the 40, 20, and 10 minute periods by the use of the planimeter, as illustrated in Fig. 2, the areas being taken between the vertical lines, which are equal maximum ordinates enclosing the given time intervals.

The first step, then, after the records are gathered and plotted, is to determine the average intensity of each rain for the different time intervals. It should not be lost sight of that these averages in no wise enter into the computations of sewer discharge, but are

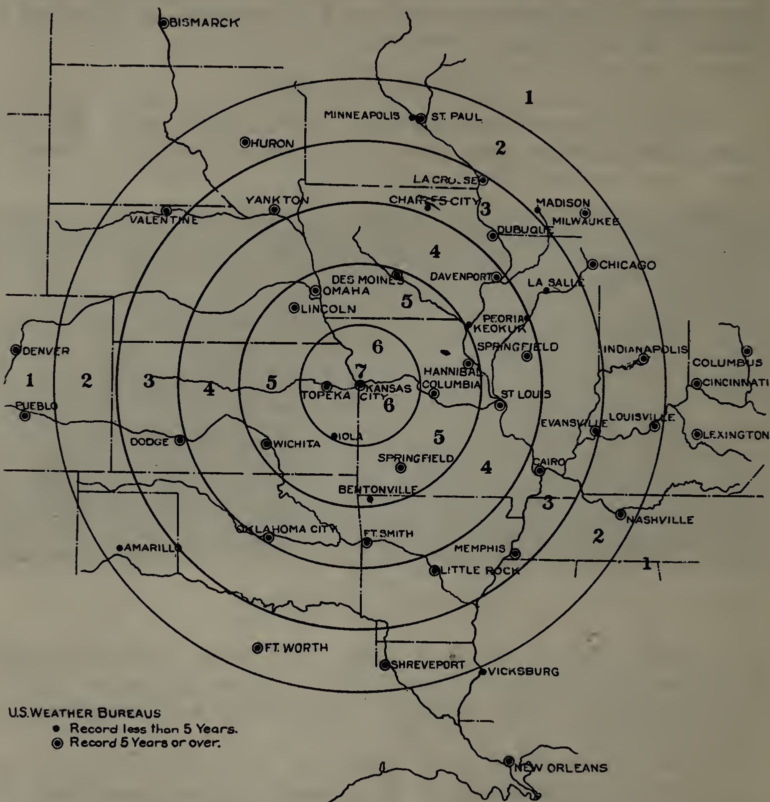

Fig. 1. Map Showing U. S. Gauging Stations.

used merely in the arrangement of the tables. Tables III, IV, and V contain the data so arranged.

Typical Precipitation Curves.—The matter of greatest importance in planning and designing a storm sewer system is the determination of typical precipitation curves. The exercise of judgment comes mainly in the selection of surcharge periods, the following work being largely a question of mathematics.

It is essential that the rainfall data be from automatic gages which record the depth in inches falling each five minutes. This makes it possible to plot curves showing both the total and rate of precipitation, the usual way being to use time as abscissas and rates per hour as ordinates.

It is unnecessary to plot the records of all rains, as much time and labor can be saved by setting a minimum limit below which rains will be omitted. The choice of this in no way affects the validity of the method or the correctness of the results secured. For the Mississippi Valley, and the Middle West generally, very satisfactory limits are as follows: a precipitation of 0.25 in. during some five minutes of the storm and a total precipitation of at least an inch of rainfall.

In order to present clearly the method of computing a typical rain curve, a simple illustration will be used. Suppose a city has ten rains in ten years; it is clear that the hardest one occurred once in the ten years; that one equal to or exceeding the next hardest occurred every five years, for it and the hardest both occurred during the ten years, or an average of every five years for the one or the other. The same line of reasoning shows that one equal to or exceeding the fifth hardest occurred every two years.

The method is still logical no matter how many rains occurred, and if the ten hardest are used, being as many as the number of years considered, it determines what rains may be expected to flood the sewers for any surcharge periods selected. Since data are used from different gaging stations, it becomes necessary to reduce their records to a common basis. Probably 10 is the most convenient one to use, so this will be employed throughout the discussion. If the record has been kept for more than 10 years, say 11 for example, each rain must be weighted by 10/11, using the actual intensity, but taking 11 instead of 10 rains into account. Likewise, if the record is available for only 6 years, each rain must be weighted by 10/6. It is hardly necessary to mention that the longer the record the more satisfactory its use, since interpolating is always preferable to exterpolating. If some number other than 10 years had been selected as standard, the numerator of the above fractions would correspond.

Another point needs to be considered at this time; all engineers will agree that cities situated in the same drainage basin may be expected to show rain curves somewhat similar in form and intensity, so that the records of all such cities may properly be considered in estimating future probabilities; they will likewise agree that a city's own rains will be a truer index of what may be expected in the future than the precipitations at other places several hundred miles distant. For this reason, the records have been weighted, giving Kansas City a weight of 7,

cities within 100 miles 6, 200 miles 5, and so on, until those at a distance greater than 500 miles, but still within the Mississippi Valley, are given a weight of 1.

Table VI, gives the final weights of the different cities, and the method of their computation. These have been obtained as follows: the number of years for which rains are considered is divided by the length of time the record is available, and this quotient is multiplied by the distance weight of the city. For Topeka, Kansas, this gives

$$10 \div 8\tfrac{1}{2} \times 6 = 7.$$

With surcharge periods of 10, 5, and 2 years already determined upon, the *Total final weight* is multiplied by 1, 2, and 5

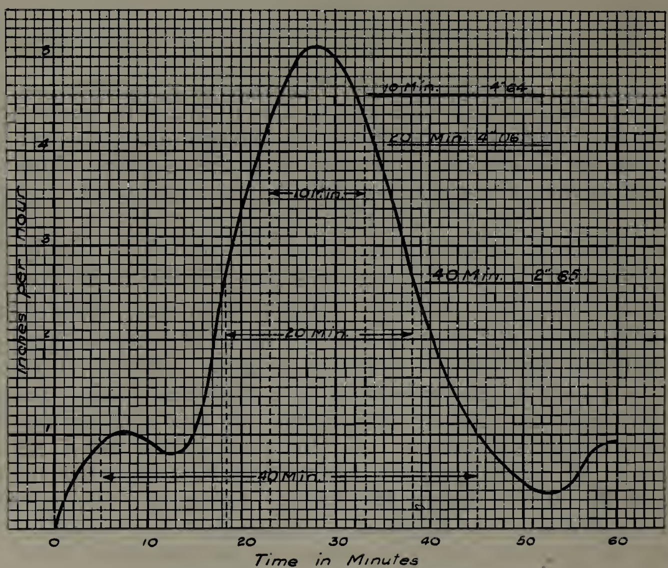

FIG. 2 = PRECIPITATION CURVE. COLUMBIA, MO.

(obtained by dividing 10 by 10, 5, and 2) as given at the bottom of Table VI. This gives partial totals of 149 to be used with Table III, 298 with Table IV, and 745 with Table V. Opposite these in the tables we find 2.62, 3.26, and 3.42, which are the average intensities of the three typical precipitation curves.

It now remains to determine the form of each of these curves. The 40 minute curve will be used to illustrate the operation. This is best seen by reference to Table IX, where it will be noticed that ten weights above and ten below have been used. Either more or less rains might have been used, depending on the judgment of the engineer as to how many are required to derive a curve which shall be truly typical in shape. Since the

intensity for the period is in no wise affected, a comparatively large error in judgment results in but slight error in design, thus reducing the personal equation to a minimum.

Table VII, gives the rains thus selected. The amount of precipitation for each 5 minutes is given, with the beginnings of the rains directly under each other. In Table VIII, these are arranged symmetrically with regard to their maximum intensities, since this arrangement is best adapted to obtaining a curve which shall most nearly represent them in its form characteristics.

In Table IX, the same arrangement is preserved, but the different values are multiplied by the respective weights of the rains taken from Table III. The columns are then added and the sums divided by 20, since a total of twenty weights was used. In order to obtain ordinate values for plotting, these quotients are multiplied by 12 so as to get rates per hour. These rates

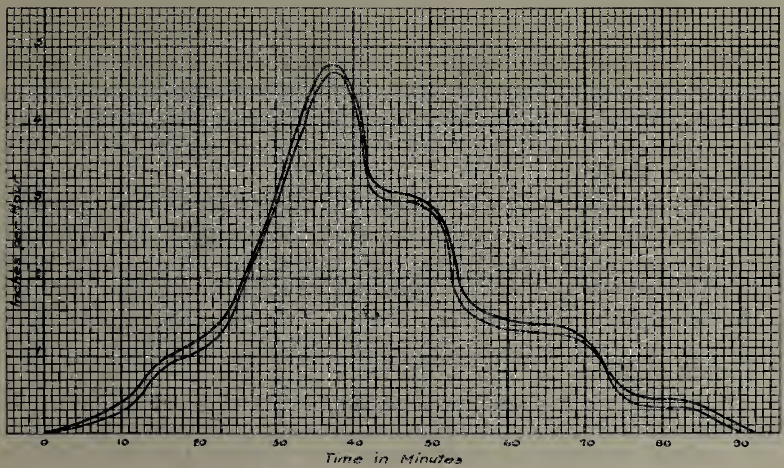

FIG. 5 - RESULTANT CURVE FOR 40 MIN. PERIOD

are given in the last line, the curve being shown by the lighter line of Fig. 5. This gives the correct form of the typical precipitation curve desired, but not necessarily its magnitude, which may be either more or less. In the present instance the curve has to be increased slightly in intensity, this being done so as to make the rate for 40 minutes 2.62 in. per hour, as given in the table. The final curve is shown by the heavier line in the figure.

As previously suggested, the method contemplates the use of a precipitation curve for each typical sewer length, varying in number probably from one to four in different cities. To make the need for this apparent, suppose the rain curve for 40 minute sewers were used for 20 and 10 minute sewers, it would in effect greatly reduce their surcharge periods.

Taking the rain immediately above 2.62, which is the average intensity for 40 minute sewers, the *Partial Totals* in the different tables are found to be 149, 796, and 1241. Dividing each of these by 149 gives 1, 5.35, and 8.33; then dividing 10 by each of these gives 10, 1.86, and 1.20. In other words, the 40 minute sewer would be flooded every ten years (which had been assumed), the 20 minute sewer a little oftener than every two years and the 10 minute sewer a little more frequently than once every fifteen months.

Or take the illustration the other way; suppose the rain curve for 10 minute sewers were used for 40 and 20 minute drains, it would have the effect of increasing their surcharge periods. The average intensity would then be 3.42, opposite 35, 229, and 745 in the columns of partial totals. Dividing as before gives final quotients of 42.6, 6.5, and 2; which means that the different classes of sewers would be flooded about every 40, 6, and 2 years respectively.

The tables can readily be used to determine the surcharge periods for any desired intensity of rain. If a precipitation can be found which will give satisfactory surcharge periods for the different classes of sewers, it would in effect reduce them to one. This is the ideal condition, but should not be expected to occur often in practice.

Designing the Sewers.—With the time length of a sewer approximated and the typical rain determined, it is then only necessary to decide from this rain curve the amount of runoff which will reach the sewer from each runoff tract, and use this in conjunction with the grade that can be secured. With these data in hand, the size of sewer and velocity of flow are readily computed.

Referring to Fig. 4, it illustrates how the runoff from the different tracts is combined so as to obtain a cumulative effect comparable with actual conditions. It will be noticed that the calculations are all graphical, this method being simple, rapid, and of sufficient accuracy. The different values might be added, but the work would be laborious and there would be greater danger of errors creeping in. By repeating this process wherever more water enters the sewer, the required size is synthetically built up.

With the velocity of flow determined, the time is computed which will be required for the water to flow from the first catch basin to the second, or to where another sewer joins it, the writer's practice being to compute time lengths for periods of five minutes or over, using the nearest five minutes in adjusting the curves. Whenever our knowledge of surface concentration shall have become sufficiently definite, it will be advisable to work to minute intervals instead of only to five minutes.

A curve is then drawn which in magnitude equals the typical

curve multiplied by the area drained, for each of the runoff tracts, the second one being moved toward the right as many minutes as the time required for the water to flow from the first point to the second. This is shown in the figure by *Tract 1* and *Tract 2*. The two curves are then combined by making a new one with ordinates equal to the sum of their ordinates above the lines of *Perviousness*. This new curve represents the flow below the junction point.

When the outlet is reached, the shape and magnitude of the last curve gives a correct graphical representation of the resulting flow to be expected at this point. At first glance it would seem

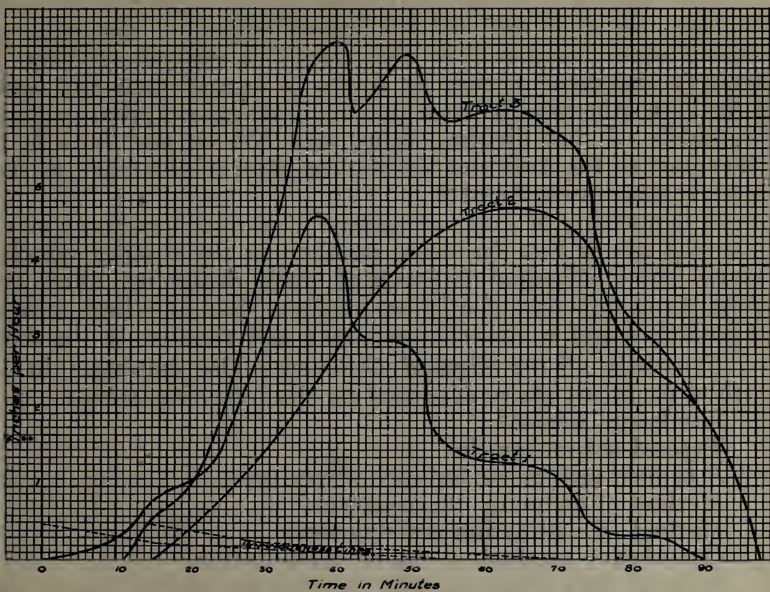

FIG. 4 - CUMULATIVE METHOD OF COMBINING DISCHARGES.

that much time would be consumed. On the contrary, it is surprising how rapidly and certainly results can be obtained.

To design a sewer for any part of the city, always begin with the laterals and work toward the branches and from that to the main sewers. In other words, follow with the computations the order followed by the water in filling sewers. Whenever advisable the method may be combined with the use of any of the formulas already mentioned.

Numbering Sewers.—If some simple and yet rational system of numbering sewer districts be adopted, it not only saves a great deal of inconvenience but much lost time and frequent errors. This may be illustrated by the method proposed for

Kansas City. By charter the entire territory within the corporate limits is divided into sewer divisions and these into sewer districts. For purposes of designing, the divisions are subdivided into drainage areas, these into runoff tracts, and these again into sewer districts. See Fig. 6.

Including the new territory, eight divisions are being proposed for the city. These are being divided into drainage areas, not to exceed nine for each division; these again into runoff tracts, not to exceed nine for each area; the tracts being divided in the same way into sewer districts, the highest possible number being 8999. As a matter of convenience, the numbers follow up the sewers. This can best be illustrated by an example.

Sewer district number 5439 means that it is located in division 5, drainage area 4 of this division, runoff tract 3 of this area, and sewer district number 9 in this tract. It also shows that the property embraced within its limits is located near the center of the city, otherwise it would not be in division 5; that it is near the middle of that division, being area No. 4; that it is in the lower part of the area and the highest part of the tract, as indicated by the figures 3 and 9.

It is not only of great advantage in at once locating a sewer, since the sewer has the same number as the district which it serves, but is of equal importance while designing, since each sewer flows into one of a lower number, thus avoiding occasion for mistakes and so insuring accuracy and rapidity in the work.

Essentials of the Method Outlined.—The emphasis in the method proposed above is placed on the following points:

Surcharge periods.

Typical sewer lengths.

A typical rain curve for each sewer type.

Method of deducing these curves.

Method of estimating perviousness.

Cumulative method of sewer computation.

Most of the earlier attempts to solve the storm flow problem considered these same features, although frequently not with such explicitness, as the requirements were not then so well understood. Aside from the method of estimating the perviousness, only brief consideration is given to the subjects of permeability and time of surface concentration, since these phases of the question still wait on the gathering of more data, so that something approaching complete and reliable information may be at hand.

Points Which Commend the Above Method.—It follows nature in being cumulative in results obtained.

.It is a combined analytic and synthetic method.

The direction of storms can readily be allowed for.

It is adapted to any degree of refinement.

There is no uncertainty as to where maximum periods occur.

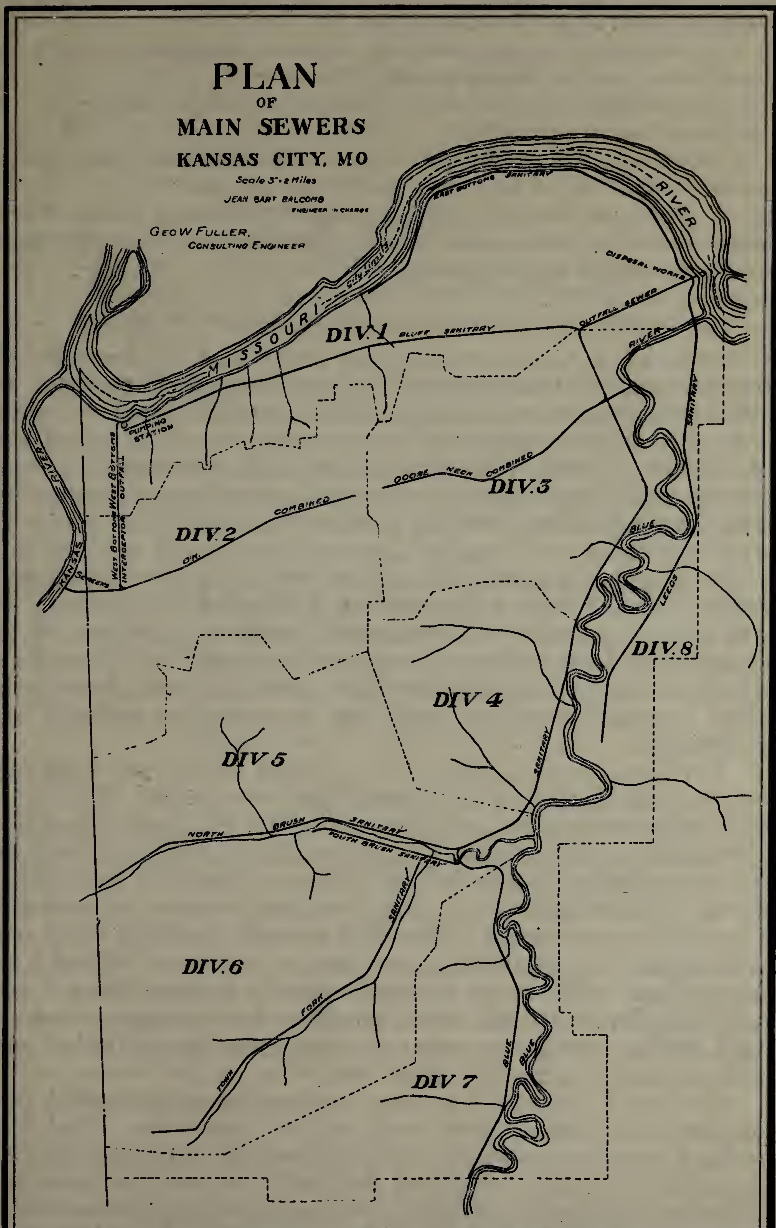

Fig. 6. Plan of Main Sewers—Kansas City, Mo.

It can be used to solve the problem independently, or in conjunction with any other method.

Wherever it is necessary to exercise judgment, the conditions to be met are definite and certain.

No averages are used in computing capacities, the actual rain variations being followed.

There are no coefficients to be approximated, with consequent probability of large and uncertain errors.

It does not depend on formulas or difficult mathematical determinations, yet secures results agreeing with the facts up to the limits of the data available.

ACTUAL CONSTRUCTION AND RESULTS TO BE EXPECTED.

Materials of Construction.—The decision as to what materials to use in construction has been controlled largely in the past, and still is to some extent, by the materials manufactured or for sale by local firms, through political affiliations, and social friendships. This is being greatly lessened owing to a closer study of the subject my municipal hydraulic engineers, and a larger interest and better understanding by the general public of the needs and requirements of a thoroughly up-to-date sewerage system.

It may be a matter of surprise to some that rectangular wooden sewers have been built in a number of instances and have given excellent service through a term of years, but finally becoming at least indirectly a public nuisance. It is not be be supposed that any engineer would recommend such construction today, as the defects of wood for this purpose are now well recognized.

For large sewers, brick was well-nigh universally used until concrete was found to be a much better material. The use of brick is growing less and less, owing to the large number of joints and the lack of tensile strength in the completed structure. This is emphatically true unless the sewers are lined with cement mortar. A special invert is also required as many serious cases of erosion are on record. The chief reasons for using brick were its cheapness, its availability, the supply of suitable skilled labor, and the ease with which vitrified brick or Belgian blocks could be laid in the invert, after this was found necessary in order to avoid their cutting out where even moderate velocities were used.

For small sewers, it is generally agreed that vitrified pipe, with bell and spigot joint well caulked and then filled with portland cement mortar, is the best material at hand. At the same time it is fully recognized that such frequent joints make it an undesirable material, partly because it is almost impossible to inspect each individual joint in its entirety, and partly because it is, to say the least, very inconvenient to do good work and make the joints water tight. When laid on steep slopes, the

joints, being of a material foreign to the pipe and adhering only fairly well, make natural places for erosion to begin. This frequently continues until water finds its way in or out of the sewer, depending on the level of the water table at different seasons of the year.

The present concensus of engineering opinion favors the use of concrete, generally reinforced, and either monolithic or in the form of pipe, for nearly all sewers larger than 30 inches inside diameter. Sewers 24 inches to 30 inches are still debatable ground. Concrete pipe with longitudinal bar reinforcement possesses many of the characteristics which must obtain in the sewer construction material of the future. It is to be hoped that a substitute for vitrified pipe may be found, or that a better joint may be devised, or else that it may be found feasible to construct small sizes of concrete pipe with an entirely satisfactory method of joining them.

Contracts and Specifications.—Much good work has been done along this line in the past few years, and yet the present forms of contract and specifications are far from satisfactory. In a letter to *Engineering-Contracting,* published February 10, 1909, the writer made the following statement, which has not thus far been questioned, and which he wishes to reiterate in the present instance:

> "In order to draw up an equitable contract, or judge of one that is drawn, the first requisite is that it shall be fair to both parties, assuming them both to be honest and actuated by right motives. The second is to have it formulated so there is no motive for dishonesty by either party—so that whether an honest or dishonest course is followed it will result in a gain or loss to both parties, never a gain to one and a loss to the other."

Of the various modifications and forms proposed, the one which seems to be entirely adequate, and at the same time adapted to existing needs and conditions, may best be described as follows: Cost plus a fixed sum, with bonus and forfeit clause regarding both the time limit and the total expenditures; all extras to be paid for by cost plus a percentage.

Inspection.—With the old form of contract, it had become tacitly understood that laxity of inspection would counterbalance rigor of contract. The result has been that it often did far more than this. Whereas the specifications called for practically a perfect sewer, the actual construction fell unwarrantably below even reasonable requirements.

On the other hand, with the more reasonable forms of contract now coming into vogue, it is beginning to be possible to make the work of the inspector something more than a matter of form, and to really get sewers built very closely in accordance with the designs. The writer is firmly of the belief that a reason-

able contract with honest inspection will correct many of the evils from which urban communities now suffer.

Maintenance.—The maintenance and repair of sewers, having been entirely removed from the engineering department in all of the larger cities, will be passed with a single thought.

While the day labor employed by cities is in many cases better than it formerly was, yet it is frequently untrustworthy and cannot be depended upon to carry out regulations regarding cleaning and flushing sewers. Also, it is notoriously inefficient. For the sake of economy, it is advisable to place automatic flush tanks at practically all dead ends, and to construct street inlets rather than catch basins, except where the latter are absolutely necessary, depending mainly on flushing to keep the sewers clean. It is also advisable, in sanitary sewers, to see that the building regulations require a vent from the soil pipe to the roof of each building, so that when sanitary sewage conveyed by the separate system has once passed the trap inside of the building, there shall be no other traps until it is finally discharged through the outfall sewer or at the disposal works.

Degree of Accuracy.—Engineers are prone to approach this problem as though it could be solved exactly. This is the desideratum, but it cannot be even closely approximated until much more experimental work has been done and a large amount of additional data has been gathered, so that judgments may be formed, rules formulated, and the practice standardized.

Engineers go to great lengths to determine the exact daily consumption per capita and the amounts of water used by manufacturing concerns, so as to know very closely the amount of house sewage and trade wastes; then very largely guess at the amount of seepage water, after which the figures are increased perhaps 50% to allow for periods of maximum flow; and then the sewer is designed, so that on the basis of these computations it will run two-thirds or three-fourths full during maximum flow.

In order to arrive at the amount of runoff, engineers make careful estimates of the perviousness of the surface, its general slope and the time of surface concentration; and then arbitrarily assume some depth of rain which may or may not closely approximate the maximum rainfall for that city, or some predetermined amount less than this maximum.

This is all necessary, and the writer warmly endorses doing all such work as accurately as possible, laying stress on the refinement of details as rapidly as our knowledge warrants such action, but it should not be expected that absolutely correct results have been attained, after all this is done. Neither is it to be inferred that in this respect the hydraulic engineer is behind the structural, mechanical, or other engineers of the profession.

A sewer system should be designed for 25 years, for 50 years, for all time; and engineers accomplish this with a remarkably small margin of error. Yet no one would think of expecting an architect or structural engineer to build a factory so that it would handle a small output economically and at the same time be capable of caring for the unknown future growth of the business. If in the erection of a steel frame building or in the construction of a machine, where working conditions are pre-determined and the strength and properties of the steel may be found out completely in the laboratory and testing machine, it is deemed necessary to allow factors of safety from 3 to 20; hydraulic engineers are to be congratulated, since many of the conditions with which they deal are difficult and some of them practically impossible to determine, yet withal satisfactory results are achieved.

Table I. Field Covered by Hydraulic Engineering.

Hydraulic Engineering	Agricultural	Drainage. Irrigation.
	Municipal	Waterworks. Sewerage.
	Power	Water. Electrical.
	Transportation	Harbor improvements. Ship canals. River improvement.

Table II. Heavy Precipitations, Giving Rates per Hour.

City.	Date.	Time Periods. 10 min.	20 min.	40 min.
Kansas City, Mo.	8-23-06	6.78 in.	6.48 in.	5.79 in.
St. Louis, Mo.	7 -8-98	6.03 in.	4.92 in.	3.66 in.
Milwaukee, Wis.	6-24-04	5.78 in.	4.64 in.	3.98 in.
Ft. Worth, Tex.	9-21-00	4.90 in.	4.14 in.	3.70 in.
Cairo, Ill.	6-28-05	4.74 in.	3.84 in.	3.32 in.
Columbus, Ohio	7-11-97	4.57 in.	4.11 in.	3.51 in.
Little Rock, Ark.	7-11-03	4.42 in.	3.98 in.	3.36 in.
Topeka, Kans.	8- 2-03	4.02 in.	3.72 in.	3.48 in.
Shreveport, La.	7-23-05	3.86 in.	3.74 in.	3.70 in.

Table III.

HEAVY PRECIPITATIONS.

40 minutes.

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Kansas City, Mo.	8-23-06	5.79	7	7
Milwaukee, Wis.	6-24-04	3.98	2	9
Shreveport, La.	7-23-05	3.70	4	13
Ft. Worth, Tex.	9-21-00	3.70	3	16
St. Louis, Mo.	7- 8-98	3.66	4	20
Columbus, O.	7-11-97	3.51	1	21
Topeka, Kans.	8-02-03	3.48	7	28
Topeka, Kans.	9-13-01	3.40	7	35
St. Paul, Minn.	8- 9-02	3.36	2	37
Little Rock, Ark.	7-11-03	3.36	3	40
Cairo, Ill.	6-28-05	3.32	3	43
Ft. Worth, Tex.	3-25-04	3.20	3	46
Columbia, Mo.	5-31-02	3.20	5	51
Little Rock, Ark.	5- 8-00	3.14	3	54
Cairo, Ill.	6-13-99	3.10	3	57
Ft. Worth, Tex.	6- 3-04	3.10	3	60
New Orleans, La.	8-25-04	3.09	1	61
Davenport, Ia.	8-26-07	3.06	7	68
Omaha, Neb.	7- 6-98	3.03	5	73
Columbus, O.	6-23-01	3.02	1	74
Wichita, Kans.	7- 6-04	2.96	10	84

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Dodge City, Kans.	6- 7-99	2.94	3	87
Wichita, Kans.	9-17-05	2.92	10	97
Louisville, Ky.	8- 8-98	2.90	2	99
New Orleans, La.	3-17-04	2.86	1	100
Nashville, Tenn.	8-21-02	2.82	2	102
New Orleans, La.	7-19-01	2.81	1	103
New Orleans, La.	7-19-01	2.81	1	104
Columbia, Mo.	8-25-00	2.78	5	109
Oklahoma City, Okla.	6- 4-04	2.78	4	113
Little Rock, Ark.	11-28-05	2.78	3	116
Kansas City, Mo.	9-14-05	2.77	7	123
Evansville, Ind.	8-14-06	2.74	4	127
Nashville, Tenn.	6-15-97	2.72	2	129
New Orleans, La.	7-11-04	2.71	1	130
Oklahoma City Okla.	5-29-05	2.70	4	134
Des Moines, Ia.	7-14-07	2.67	5	139
Evansville, Ind.	9- 2-00	2.66	4	143
Lexington, Ky.	8-22-00	2.65	1	144
Columbia, Mo.	8-22-05	2.65	5	149

(149 weighted rains occur every 10 years.)

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Shreveport, La.	6- 1-06	2.62	4	153
New Orleans, La.	3-14-03	2.60	1	154
Springfield, Mo.	7-26-05	2.58	10	164
Topeka, Kans.	6-24-03	2.58	7	171
Little Rock, Ark.	5-21-98	2.56	3	174
Hannibal, Mo.	5-26-06	2.54	5	179
Wichita, Kans.	6-15-05	2.53	10	189
Nashville, Tenn.	9- 1-00	2.53	2	191
New Orleans, La.	3-14-03	2.51	1	192
Little Rock, Ark.	9-15-98	2.50	3	195
Milwaukee, Wis.	9- 2-00	2.50	2	197
Cincinnati, O.	7- 5-97	2.50	1	198
Dubuque, Ia.	8-15-07	2.50	5	203
Shreveport, La.	6-27-02	2.47	4	207
Lincoln, Neb.	5-10-05	2.45	6	213
New Orleans, La.	3-14-03	2.44	1	214

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Springfield, Mo.	7-19-06	2.44	10	224
Davenport, Ia.	9- 9-03	2.44	7	231
Nashville, Tenn.	6-15-05	2.43	2	233
Ft. Worth, Tex.	5- 2-06	2.40	3	236
Memphis, Tenn.	8- 9-05	2.38	3	239
Nashville, Tenn.	9- 4-06	2.38	2	241
Nashville, Tenn.	6- 9-03	2.38	2	243
New Orleans, La.	4-25-07	2.37	1	244
Columbia, Mo.	5-25-03	2.37	5	249
Milwaukee, Wis.	9-17-07	2.36	2	251
Lincoln, Neb.	8-15-00	2.32	6	257
Dodge City, Kans.	8-18-04	2.32	3	260
Kansas City, Mo.	9- 9-03	2.32	7	267
Oklahoma City, Okla.	5- 5-99	2.32	4	271
Dodge City, Kans.	7-19-97	2.32	3	274

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
New Orleans, La.	8- 5-98	2.30	1	275
Kansas City, Mo.	3-24-04	2.30	7	282
Huron, S. D.	8- 8-04	2.30	2	284
New Orleans, La.	7-11-06	2.29	1	285
Kansas City, Mo.	7-14-07	2.26	7	292
Dodge City, Kans.	7-21-07	2.26	3	295
Huron, S. D.	6-27-05	2.26	2	297
La Crosse, Wis.	7- 9-03	2.26	5	302
Columbia, Mo.	6-25-99	2.24	5	307
Shreveport, La.	4-11-05	2.24	4	311
Yankton, S. D.	8-23-06	2.22	3	314
St. Louis, Mo.	8- 6-07	2.20	4	318
Little Rock, Ark.	6- 1-98	2.20	3	321
Hannibal, Mo.	8- 8-99	2.20	5	326
Milwaukee, Wis.	8-23-98	2.20	2	328
Cincinnati, O.	7-22-06	2.19	1	329
Dodge City, Kans.	6-17-06	2.18	3	332
St. Paul, Minn.	7-30-04	2.16	2	334
Wichita, Kans.	7-14-04	2.16	10	344
Evansville, Ind.	9- 2-04	2.16	4	348
Columbia, Mo.	9-17-05	2.15	5	353
Shreveport, La.	5- 7-07	2.14	4	357
Columbia, Mo.	6-14-98	2.12	5	362
Indianapolis, Ind.	3-31-04	2.12	2	364
Cairo, Ill.	6-22-97	2.11	3	367
New Orleans, La.	5-23-07	2.10	1	368
St. Paul, Minn.	8-18-07	2.10	2	370
New Orleans, La.	4-17-01	2.08	1	371
Ft. Smith, Ark.	6-30-07	2.08	7	378
Des Moines, Ia.	7-18-04	2.08	5	383
New Orleans, La.	9-16-01	2.06	1	384
Oklahoma City Okla.	5-23-03	2.06	4	388
Yankton, S. D.	9-20-02	2.06	3	391
Valentine, Neb.	7-21-04	2.06	3	394
Kansas City, Mo.	8- 2-05	2.06	7	401
Evansville, Ind.	7-20-04	2.06	4	405
Dodge City, Kans.	7-23-99	2.06	3	408
Shreveport, La.	5- 3-06	2.05	4	412
Valentine, Neb.	7- 9-07	2.04	3	415
Memphis, Tenn.	7-16-06	2.04	3	418
Cairo, Ill.	6- 7-00	2.04	3	421
St. Paul, Minn.	6-12-99	2.04	2	423
New Orleans, La.	7- 4-03	2.04	1	424
Yankton, S. D.	7-15-00	2.04	3	427
Springfield, Mo.	6-24-06	2.03	10	437
Columbus, O.	7-28-02	2.02	1	438
Dodge City, Kans.	8- 6-98	2.02	3	441
Columbia, Mo.	9-18-04	2.02	5	446
Kansas City, Mo.	5-23-02	2.02	7	453
New Orleans, La.	7-15-01	2.01	1	454
Wichita, Kans.	5-20-03	2.00	10	464
Lincoln, Neb.	5-28-05	2.00	6	470
Evansville, Ind.	5-30-00	2.00	4	474
La Crosse, Wis.	8- 4-05	1.98	5	479
Yankton, S. D.	7-14-00	1.96	3	482
Memphis, Tenn.	11-19-06	1.96	3	485
Nashville Tenn.	6- 7-00	1.95	2	487
Hannibal, Mo.	6- 4-04	1.95	5	492
Lincoln, Neb.	7-15-00	1.95	6	498
Ft. Worth, Tex.	6-24-03	1.94	3	501
Valentine, Neb.	6-27-05	1.94	3	504
Indianapolis, Ind.	8- 2-99	1.93	2	506
Yankton, S. D.	7-10-07	1.92	3	509
New Orleans, La.	8- 3-02	1.92	1	510
St. Paul, Minn.	10- 3-03	1.92	2	512
New Orleans, La.	4-17-00	1.91	1	513
Kansas City, Mo.	6-22-01	1.90	7	520
New Orleans, La.	11-22-01	1.90	1	521
Evansville, Ind.	7-11-04	1.90	4	525
Hannibal, Mo.	9-25-98	1.89	5	530
Indianapolis, Ind.	8-19-06	1.89	2	532
New Orleans, La.	7-17-97	1.88	1	533
Ft. Worth, Tex.	7-28-06	1.88	3	536
Yankton, S. D.	5-24-06	1.88	3	539

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Oklahoma City Okla.	8-28-00	1.87	4	543
Huron, S. D.	6-24-02	1.86	2	545
Topeka, Kans.	9-22-02	1.85	7	552
Louisville, Ky.	7-10-97	1.84	2	554
Columbus, O.	7-19-00	1.84	1	555
Nashville, Tenn.	7-11-97	1.84	2	557
Columbia, Mo.	10- 6-00	1.84	5	562
Lincoln, Neb.	8- 7-07	1.84	6	568
Lincoln, Neb.	7-22-02	1.84	6	574
St. Paul, Minn.	9- 5-04	1.84	2	576
Kansas City, Mo.	9- 5-98	1.84	7	583
Davenport, Ia.	9-14-03	1.84	7	590
Des Moines, Ia.	4-22-97	1.83	5	595
Omaha, Neb.	6-26-06	1.82	5	600
New Orleans, La.	8-12-06	1.82	1	601
Ft. Worth, Tex.	8-11-06	1.82	3	604
Cincinnati, O.	8- 3-00	1.81	1	605
Chicago, Ill.	7-28-06	1.80	2	607
St. Paul, Minn.	7-25-97	1.80	2	609
New Orleans, La.	6- 7-04	1.80	1	610
Topeka, Kans.	8- 4-06	1.80	7	617
Little Rock, Ark.	4-24-05	1.78	3	620
New Orleans, La.	6-20-00	1.78	1	621
Little Rock, Ark.	7-29-00	1.78	3	624
Hannibal, Mo.	7- 7-98	1.76	5	629
Huron, S. D.	8- 8-01	1.76	2	631
Oklahoma City Okla.	8- 7-06	1.76	4	635
Omaha, Neb.	7-15-00	1.75	5	640
Indianapolis, Ind.	6- 4-06	1.75	2	642
Columbia, Mo.	4-24-04	1.74	5	647
Wichita, Kans.	6- 2-04	1.74	10	657
St. Louis, Mo.	7-29-03	1.73	4	661
Dodge City, Kans.	5-13-98	1.72	3	664
New Orleans, La.	3-19-05	1.72	1	665
Nashville, Tenn.	6-27-04	1.72	2	667
Shreveport, La.	4- 2-05	1.72	4	671
Shreveport, La.	5-21-05	1.72	4	675
Huron, S. D.	8-18-04	1.71	2	677
Bismarck, N. D.	6-13-01	1.71	1	678
Kansas City, Mo.	7- 7-02	1.71	7	685
Columbus, O.	6-14-04	1.71	1	686
Shreveport, La.	7-23-02	1.70	4	690
Columbia, Mo.	7-18-02	1.68	5	695
Dodge City, Kans.	8- 6-03	1.68	3	698
Springfield, Mo.	8- 7-06	1.68	10	708
Ft. Worth, Tex.	5- 3-04	1.68	3	711
Cairo, Ill.	7-30-01	1.68	3	714
Dubuque, Ia.	9-25-04	1.68	5	719
Des Moines, Ia.	7-19-04	1.66	5	724
Little Rock, Ark.	8-25-99	1.66	3	727
Indianapolis, Ind.	7- 6-04	1.65	2	729
New Orleans, La.	9- 9-98	1.65	1	730
Oklahoma City Okla.	8-12-01	1.64	4	734
Springfield, Mo.	6- 4-04	1.64	10	744
Lexington, Ky.	7-19-02	1.63	1	745
Des Moines, Ia.	7-19-05	1.62	5	750
Memphis, Tenn.	8-18-01	1.62	3	753
St. Paul, Minn.	8- 5-98	1.62	2	755
Nashville, Tenn.	9-14-01	1.61	2	757
Oklahoma City Okla.	5-28-03	1.60	4	761
Columbia, Mo.	10-28-00	1.60	5	766
Des Moines, Ia.	7-16-07	1.60	5	771
Chicago, Ill.	5-24-02	1.59	2	773
New Orleans, La.	7-18-00	1.59	1	774
Dodge City, Kans.	7-28-00	1.58	3	777
Cincinnati, O.	7-21-03	1.58	1	778
Hannibal, Mo.	8- 8-99	1.56	5	783
Columbia, Mo.	10-16-05	1.56	5	788
Louisville, Ky.	3-16-98	1.55	2	790
Omaha, Neb.	8-26-03	1.54	5	795
Lincoln, Neb.	8- 4-02	1.54	6	801
Ft. Smith, Ark.	9- 2-06	1.54	7	808

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Bismarck, N. D.	6- 4-05	1.53	1	809
Indianapolis, Ind.	5-29-00	1.53	2	811
Bismarck, N. D.	6-16-97	1.53	1	812
Louisville, Ky.	6-15-02	1.52	2	814
Columbus, O.	8-15-00	1.52	1	815
St. Louis, Mo.	5- 5-00	1.51	4	819
New Orleans, La.	11- 9-98	1.51	1	820
Kansas City, Mo.	9- 6-05	1.50	7	827
New Orleans, La.	7- 5-02	1.50	1	828
St. Paul, Minn.	10- 3-00	1.50	2	830
St. Louis, Mo.	5-21-98	1.49	4	834
New Orleans, La.	7-25-99	1.49	1	835
Topeka, Kans.	7-31-02	1.48	7	842
Columbia, Mo.	6- 7-98	1.48	5	847
Memphis, Tenn.	3-26-02	1.48	3	850
Oklahoma City Okla.	7-20-97	1.46	4	854
Oklahoma City Okla.	5- 6-00	1.46	4	858
Chicago, Ill.	7- 9-03	1.44	2	860
Omaha, Neb.	6-16-00	1.44	5	865
Springfield, Ill.	8- 3-05	1.44	6	871
Springfield, Ill.	6- 1-02	1.44	6	877
Kansas City, Mo.	7- 5-04	1.44	7	884
Memphis, Tenn.	5-26-02	1.44	3	887
Dodge City, Kans.	10- 9-98	1.42	3	890
Lincoln, Neb.	5-24-03	1.42	6	896
Ft. Worth, Tex.	9-21-00	1.42	3	899
Ft. Worth, Tex.	5-24-07	1.42	3	902
Lincoln, Neb.	9-14-06	1.42	6	908
Des Moines, Ia.	7-23-00	1.40	5	913
Oklahoma City Okla.	9-11-06	1.40	4	917
Yankton, S. D.	9-20-02	1.40	3	920
Huron, S. D.	8- 4-00	1.40	2	922
Hannibal, Mo.	8-10-99	1.40	5	927
New Orleans, La.	10- 7-00	1.38	1	928
Lincoln, Neb.	9-16-06	1.37	6	934
Milwaukee, Wis.	9-14-03	1.34	2	936
Kansas City, Mo.	7-19-06	1.30	7	943
St. Paul, Minn.	8- 4-05	1.28	2	945
Little Rock, Ark.	9-10-99	1.26	3	948
Milwaukee, Wis.	6-12-99	1.25	2	950
Des Moines, Ia.	5-21-03	1.24	5	955
Kansas City, Mo.	8-21-04	1.22	7	962
Little Rock, Ark.	12-13-01	1.14	3	965
Huron, S. D.	5- 9-05	1.09	2	967
Oklahoma City Okla.	3-25-02	1.06	4	971
Des Moines, Ia.	4-17-00	.93	5	976
New Orleans, La.	4-25-07	.80	1	977

Table IV.

HEAVY PRECIPITATIONS.

20 MINUTES.

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Kansas City, Mo.	8-23-06	6.48	7	7
New Orleans, La.	9-30-05	6.07	1	8
New Orleans, La.	5-30-07	5.16	1	9
Cincinnati, O.	5-20-02	5.03	1	10
St. Louis, Mo.	7- 8-98	4.92	4	14
St. Paul, Minn.	8- 9-02	4.92	2	16
Hannibal, Mo.	8-17-06	4.68	5	21
New Orleans, La.	8-25-04	4.65	1	22
Milwaukee, Wis.	6-24-04	4.64	2	24
Nashville, Tenn.	11-20-00	4.60	2	26
Columbus, O.	6-23-01	4.49	1	27
Des Moines, Ia.	7-19-04	4.41	5	32
Omaha, Neb.	7- 6-98	4.24	5	37
Springfield, Mo.	5-31-06	4.24	10	47
Wichita, Kans.	9-17-05	4.20	10	57
Ft. Worth, Tex.	9-21-00	4.14	3	60
Columbus, O.	7-11-97	4.11	1	61
Columbia, Mo.	8-22-05	4.06	5	66
Nashville, Tenn.	8-21-02	4.02	2	68
Davenport, Ia.	9- 1-05	4.00	7	75
Little Rock, Ark.	7-11-03	3.98	3	78
New Orleans, La.	7-18-01	3.95	1	79
Springfield, Mo.	7-26-05	3.92	10	89
Nashville, Tenn.	6-15-97	3.92	2	91
Columbia, Mo.	5-31-02	3.90	11	102
Cairo, Ill.	6-28-05	3.84	3	105
Hannibal, Mo.	9- 9-03	3.81	5	110
Huron, S. D.	7- 6-05	3.81	2	112
Louisville, Ky.	8- 8-98	3.80	2	114
Ft. Worth, Tex.	6- 3-04	3.78	3	117
Columbia, Mo.	6-25-99	3.78	5	122
New Orleans, La.	3-17-04	3.77	1	123
Nashville, Tenn.	7-19-04	3.75	2	125
Ft. Worth, Tex.	3-25-04	3.74	3	128
Shreveport, La.	7-23-05	3.74	4	132
Topeka, Kans.	8- 2-03	3.72	7	139
Columbia, Mo.	8-25-00	3.72	5	144
Wichita, Kans.	7- 6-04	3.72	10	154
Ft. Worth, Tex.	7- 2-05	3.70	3	157
Lincoln, Neb.	8-15-00	3.68	6	163
Little Rock, Ark.	5-21-98	3.66	3	166
Memphis, Tenn.	6- 7-05	3.64	3	169
Springfield, Mo.	8-14-05	3.64	10	179
Oklahoma City Okla.	6- 4-04	3.62	4	183
New Orleans, La.	4-25-07	3.60	1	184
Indianapolis, Ind.	7-25-97	3.60	2	186
New Orleans, La.	7-11-07	3.58	1	187
Cairo, Ill.	6-13-99	3.58	3	190
Topeka, Kans.	9-13-01	3.56	7	197
Davenport, Ia.	7-10-07	3.55	7	204
Des Moines, Ia.	5-28-00	3.54	5	209
Huron, S. D.	6-14-01	3.54	2	211
Indianapolis, Ind.	8- 9-99	3.52	2	213
Topeka, Kans.	6-24-03	3.48	7	220
Kansas City, Mo.	6-22-06	3.46	7	227
Cincinnati, O.	7-22-06	3.43	1	228
Denver, Colo.	5-27-98	3.42	1	229
New Orleans, La.	8-22-03	3.42	1	230
Kansas City, Mo.	9-14-05	3.40	7	237
New Orleans, La.	7-15-01	3.40	1	238
St. Louis, Mo.	8- 6-07	3.40	4	242
Oklahoma City Okla.	5-29-05	3.38	4	246
Nashville, Tenn.	6-15-05	3.38	2	248
Dodge City, Kans.	6- 7-99	3.38	3	251
Davenport, Ia.	7-10-07	3.36	7	258
New Orleans, La.	4-17-01	3.36	1	259
Des Moines, Ia.	7-14-07	3.36	5	264
New Orleans, La.	7-19-01	3.35	1	265
Columbia, Mo.	7- 2-05	3.34	5	270
Indianapolis, Ind.	9-30-02	3.34	2	272
Dodge City, Kans.	6- 4-98	3.34	3	275
New Orleans, La.	3-14-03	3.33	1	276
Topeka, Kans.	7-21-04	3.32	7	283
Chicago, Ill.	7-15-06	3.30	2	285
Lexington, Ky.	8-22-00	3.30	1	286
Louisville, Ky.	5-31-03	3.29	2	288
Nashville, Tenn.	9- 1-00	3.29	2	290
Dubuque, Ia.	8-15-07	3.28	5	295

(298 weighted rains every 5 years.)

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Columbia, Mo.....	9-16-05	3.26	5	300
Nashville, Tenn...	6- 7-00	3.26	2	302
St. Louis, Mo....	5- 1-99	3.25	4	306
St. Louis, Mo.....	5- 4-02	3.25	4	310
Little Rock, Ark...	5- 8-00	3.24	3	313
Huron, S. D......	6-12-00	3.24	2	315
Shreveport, La...	6- 1-06	3.24	4	319
Dodge City, Kas..	8- 6-98	3.22	3	322
Milwaukee, Wis...	9- 2-00	3.22	2	324
New Orleans, La..	3-30-99	3.22	1	325
Chicago, Ill.......	8- 5-05	3.20	2	327
Wichita, Kans.....	7-14-04	3.20	10	337
Davenport, Ia.....	9- 1-05	3.20	7	344
St. Louis, Mo.....	7-24-00	3.20	4	348
Dodge City, Kans..	8-18-04	3.20	3	351
Lincoln, Neb......	8-17-97	3.19	6	357
Shreveport, La....	4-11-05	3.18	4	361
Des Moines, Ia....	7-19-05	3.18	5	366
St. Louis, Mo....	6-13-00	3.18	4	370
Indianapolis, Ind..	8-19-01	3.18	2	372
New Orleans, La..	7-11-04	3.17	1	373
New Orleans, La..	12-22-07	3.17	1	374
New Orleans, La..	8-22-03	3.16	1	375
Springfield, Ill....	8- 7-07	3.16	6	381
Little Rock, Ark...	9-15-98	3.16	3	384
Lincoln, Neb......	7-15-00	3.16	6	390
Denver, Colo......	9-20-02	3.16	1	391
New Orleans, La..	3-14-03	3.15	1	392
Cairo, Ill..........	8- 7-06	3.14	3	395
Evansville, Ind....	9- 2-00	3.14	4	399
New Orleans, La..	7-10-07	3.14	1	400
Nashville, Tenn...	6-28-00	3.13	2	402
Lincoln, Neb.....	4-23-97	3.12	6	408
New Orleans, La..	7- 6-04	3.11	1	409
Yankton, S. D....	7-15-00	3.10	3	412
Hannibal, Mo.....	8-13-04	3.10	5	417
New Orleans, La..	6-22-03	3.10	1	418
St. Paul, Minn....	10- 3-03	3.10	2	420
Huron, S. D......	6-27-05	3.10	2	422
Ft. Worth, Tex....	6- 5-07	3.10	3	425
Wichita, Kans....	8- 1-03	3.10	10	435
Hannibal, Mo.....	9- 4-98	3.09	5	440
Ft. Worth, Tex...	6-20-06	3.08	3	443
Oklahoma City Okla.	9-11-06	3.08	4	447
Lexington, Ky.....	7-28-04	3.08	1	448
Dodge City, Kans..	6-17-06	3.08	3	451
Nashville, Tenn...	9- 4-06	3.07	2	453
Evansville, Ind....	5- 8-00	3.06	4	457
Ft. Worth, Tex...	7-28-06	3.06	3	460
New Orleans, La..	8-24-03	3.06	1	461
Memphis, Tenn....	8- 9-05	3.06	3	464
Ft. Worth, Tex...	5- 2-06	3.04	3	467
Huron, S. D......	8- 8-04	3.04	2	469
New Orleans, La..	6- 4-05	3.03	1	470
Wichita, Kans.....	6-15-05	3.00	10	480
Memphis, Tenn....	3- 9-01	3.00	2	482
Yankton, S. D.....	8-23-06	3.00	3	485
Little Rock, Ark...	5-12-05	2.98	3	488
St. Paul, Minn....	6-28-01	2.98	2	490
Lexington, Ky....	8-23-05	2.98	1	491
Bismarck, N. D...	6-13-01	2.97	1	492
Yankton, S. D....	7-14-00	2.96	3	495
Oklahoma City Okla.	5- 5-99	2.96	4	499
Kansas City, Mo...	5-24-05	2.96	7	506
Kansas City, Mo...	8- 2-05	2.96	7	513
Chicago, Ill......	7-28-06	2.96	2	515
Evansville, Ind...	8- 5-03	2.96	4	519
Lincoln, Neb.....	7-31-03	2.96	6	525
La Crosse, Wis...	7- 9-03	2.96	5	530
Nashville, Tenn...	7-10-97	2.95	2	532
Huron, S. D......	7-20-07	2.95	2	534
St. Louis, Mo.....	7- 4-99	2.94	4	538
New Orleans, La..	8-25-03	2.94	1	539
Chicago, Ill......	7- 1-01	2.92	2	541

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Hannibal, Mo.....	9-25-98	2.92	5	546
Bismarck, N. D...	6-16-97	2.92	1	547
Evansville, Ind...	7-20-04	2.92	4	551
Indianapolis, Ind..	3-31-04	2.92	2	553
Davenport, Ia.....	9-25-04	2.91	7	560
New Orleans, La..	8- 5-07	2.91	1	561
Ft. Worth, Tex...	5-11-05	2.90	3	564
St. Paul, Minn....	9-25-06	2.90	2	566
Yankton, S. D....	8-18-99	2.90	3	569
New Orleans, La..	9-16-01	2.90	1	570
Evansville, Ind...	9- 2-04	2.90	4	574
Denver, Colo.....	6- 2-00	2.88	1	575
Hannibal, Mo.....	5-26-06	2.88	5	580
Little Rock, Ark..	11-28-05	2.88	3	583
Dodge City, Kans.	7-23-99	2.88	3	586
Columbus, O.....	7-28-02	2.88	1	587
Evansville, Ind...	8-14-06	2.86	4	591
Hannibal, Mo....	8- 8-99	2.86	5	596
Dodge City, Kans..	6- 7-99	2.86	3	599
St. Paul, Minn...	9- 5-04	2.86	2	601
Omaha, Neb.......	7-18-07	2.85	5	606
Valentine, Neb....	7-21-04	2.84	3	609
Shreveport, La....	7-23-02	2.84	4	613
New Orleans, La..	8- 5-98	2.84	1	614
Columbia, Mo.....	6-14-98	2.83	5	619
Chicago, Ill.......	5-11-05	2.82	2	621
Shreveport, La...	6-27-02	2.82	4	625
Oklahoma City Okla.	8-28-00	2.81	4	629
Dodge City, Kans..	7-19-97	2.80	3	632
Memphis, Tenn....	6-23-99	2.80	3	635
Columbia, Mo.....	7-31-99	2.80	5	641
Columbia, Mo.....	9-18-04	2.80	5	646
Topeka, Kans.....	7-28-01	2.79	7	653
Springfield, Mo....	7-19-06	2.79	10	663
Indianapolis, Ind..	8-12-00	2.78	2	665
Kansas City, Mo...	8-21-04	2.78	7	672
Columbus, O......	6-14-04	2.77	1	673
Huron, S. D.......	8- 8-01	2.77	2	675
New Orleans, La..	4-25-07	2.77	1	676
Kansas City, Mo...	5-23-02	2.76	7	683
New Orleans, La..	6-27-04	2.76	1	684
Lincoln, Neb......	5-28-05	2.75	6	690
Nashville, Tenn...	6- 9-03	2.75	2	692
Shreveport, La....	5- 3-06	2.75	4	696
Ft. Worth, Tex....	6-24-03	2.74	3	699
Little Rock, Ark...	6- 1-98	2.74	3	702
Kansas City, Mo..	7-14-07	2.74	7	709
Huron, S. D......	6-24-02	2.74	2	711
Dodge City, Kans..	8-16-07	2.74	3	714
New Orleans, La..	6- 7-04	2.74	1	715
Omaha, Neb.......	6-26-06	2.74	5	720
New Orleans, La..	3-14-03	2.74	1	721
Indianapolis, Ind..	8-19-06	2.73	2	723
New Orleans, La..	7-11-06	2.71	1	724
Topeka, Kans.....	8-26-02	2.71	7	731
Hannibal, Mo.....	6- 4-04	2.70	5	736
Valentine, Neb....	7- 6-07	2.70	3	739
Lincoln, Neb......	8- 4-07	2.70	6	745
Kansas City, Mo...	7- 2-05	2.70	7	752
Wichita, Kans....	5-20-03	2.68	10	762
Kansas City, Mo..	6-22-01	2.68	7	769
New Orleans, La..	8-12-06	2.68	1	770
Louisville, Ky.....	7-10-97	2.68	2	772
New Orleans, La..	6-20-00	2.68	1	773
New Orleans, La..	7- 4-03	2.67	1	774
St. Paul, Minn....	6-14-01	2.66	2	776
Shreveport, La....	5-21-05	2.66	4	780
Milwaukee, Wis...	8-23-98	2.65	2	782
Indianapolis, Ind..	7- 6-04	2.64	2	784
Davenport, Ia.....	9- 9-03	2.64	7	791
Yankton, S. D.....	7-10-07	2.64	3	794
Bismarck, N. D...	10- 1-98	2.63	1	795
Lexington, Ky.....	5-10-05	2.63	1	796
Dodge City, Kans..	7-21-07	2.62	3	799
New Orleans, La..	4-17-00	2.62	1	800

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Valentine, Neb.....	6-27-05	2.62	3	803
La Crosse, Wis....	7-21-07	2.62	5	808
Wichita, Kans.....	6- 2-04	2.62	10	818
St. Louis, Mo.....	5-21-98	2.62	4	822
Wichita, Kans.....	8-16-07	2.61	10	832
Kansas City, Mo...	8-15-03	2.61	7	839
Oklahoma City Okla.	5- 6-99	2.61	4	843
Nashville, Tenn....	7-11-97	2.61	2	845
Evansville, Ind....	7-11-04	2.60	4	849
St. Louis, Mo.....	5-31-03	2.60	4	853
Memphis, Tenn....	8-30-97	2.60	3	856
Indianapolis, Ind..	8- 2-99	2.60	2	858
Wichita, Kans.....	6- 2-05	2.59	10	868
Oklahoma City Okla.	5-28-03	2.58	4	872
Ft. Smith, Ark....	8-26-04	2.58	7	879
Little Rock, Ark...	7-29-00	2.58	3	882
Davenport, Ia.....	9-14-03	2.58	7	889
St. Paul, Minn....	8- 5-98	2.58	2	891
Des Moines, Ia....	4-22-97	2.57	5	896
Kansas City, Mo...	7- 7-02	2.57	7	903
Kansas City, Mo..	3-24-04	2.56	7	910
Hannibal, Mo.....	7- 4-99	2.56	5	915
Springfield, Ill.....	5- 5-01	2.56	6	921
Columbia, Mo.....	5-25-03	2.56	5	926
Kansas City, Mo..	9- 5-98	2.56	7	933
Cairo, Ill.........	6- 7-00	2.56	3	936
Ft. Worth, Tex....	5- 3-04	2.54	3	939
Lexington, Ky.....	7-19-02	2.54	1	940
Shreveport, La....	4- 2-05	2.54	4	944
Bismarck, N. D....	6- 4-05	2.54	1	945
Columbia, Mo.....	10-16-05	2.53	5	950
Columbia, Mo......	4-25-02	2.52	5	955
Lincoln, Neb......	7-22-02	2.52	6	961
Evansville, Ind....	7-10-05	2.52	4	965
New Orleans, La..	3-19-05	2.50	1	966
Memphis, Tenn....	11-19-06	2.50	3	969
Cincinnati, O......	5-29-99	2.50	1	970
Memphis, Tenn....	8-18-01	2.48	3	973
New Orleans, La..	7- 7-98	2.48	1	974
Evansville, Ind....	6- 2-04	2.48	4	978
Columbus, O......	7-20-97	2.48	1	979
Kansas City, Mo...	9- 9-03	2.48	7	986
New Orleans, La..	11-22-01	2.48	1	987
Oklahoma City Okla.	8-11-02	2.46	4	991
Cincinnati, O......	8- 3-00	2.46	1	992
Milwaukee, Wis...	7-21-07	2.46	2	994
Little Rock, Ark..	8-25-99	2.46	3	997
Little Rock, Ark..	6-22-04	2.46	3	1000
Springfield, Mo....	6- 4-04	2.45	10	1010
New Orleans, La..	5-23-07	2.45	1	1011
Columbia, Mo.....	10-28-00	2.44	5	1016
Lincoln, Neb......	8- 4-02	2.44	6	1022
Topeka, Kans.....	9-22-02	2.42	7	1029
Oklahoma City Okla.	5-23-03	2.42	4	1033
Oklahoma City Okla.	8- 7-06	2.42	4	1037
Ft. Worth, Tex...	10-21-00	2.42	3	1040
St. Paul, Minn....	8-18-07	2.42	2	1042
Evansville, Ind....	5-30-00	2.42	4	1046
Cairo, Ill.........	6-22-97	2.42	3	1049
Little Rock, Ark..	4-24-05	2.40	3	1052
Springfield, Ill....	6- 1-02	2.40	5	1057
St. Louis, Mo....	7-29-03	2.40	4	1061
St. Louis, Mo....	5- 5-00	2.39	4	1065
Wichita, Kans.....	10-30-03	2.38	10	1075
Columbia, Mo....	10- 6-00	2.37	5	1080
Valentine, Neb...	7-11-06	2.36	3	1083
Ft. Worth, Tex..	8-11-06	2.36	3	1086
New Orleans, La..	8- 3-02	2.34	1	1087
Kansas City, Mo..	9- 6-05	2.34	7	1094
St. Paul, Minn...	7-30-04	2.32	2	1096
Kansas City, Mo..	7-19-06	2.32	7	1103
Yankton, S. D...	5-24-06	2.32	3	1106
Omaha, Neb......	7-15-00	2.32	5	1111
Valentine, Neb....	7- 9-07	2.32	3	1114
Shreveport, La...	5- 7-07	2.32	4	1118
Springfield, Mo...	6-24-06	2.31	10	1128
New Orleans, La..	7-18-00	2.31	1	1129
Evansville, Ind...	5-31-07	2.30	4	1133
Columbia, Mo....	7-18-02	2.30	5	1138
Little Rock, Ark..	9-10-99	2.30	3	1141
New Orleans, La..	7-17-97	2.29	1	1142
Lincoln, Neb.....	9-14-06	2.28	6	1148
Yankton, S. D...	9-20-02	2.28	3	1151
Columbus, O.....	7-19-00	2.28	1	1152
Nashville, Tenn..	6-27-04	2.28	2	1154
Omaha, Neb......	6-16-00	2.26	5	1159
Chicago, Ill......	5-24-02	2.26	2	1161
Des Moines, Ia..	7-23-00	2.25	5	1166
Dodge City, Kans.	10- 9-98	2.24	3	1169
Hannibal, Mo.....	8- 8-99	2.24	5	1174
Lincoln, Neb.....	8- 7-07	2.24	6	1180
Indianapolis, Ind..	5-29-00	2.23	2	1182
New Orleans, La..	8- 3-98	2.23	1	1183
St. Paul, Minn...	6-12-99	2.22	2	1185
Oklahoma City Okla.	3-25-02	2.22	4	1189
Des Moines, Ia...	4-17-00	2.21	5	1194
New Orleans, La..	9- 9-98	2.18	1	1195
Dubuque, Ia......	9-25-04	2.18	5	1200
St. Paul, Minn...	8- 4-05	2.18	2	1202
Des Moines, Ia...	7-16-07	2.18	5	1207
New Orleans, La..	7-25-99	2.17	1	1208
Des Moines, Ia...	7-18-04	2.17	5	1213
Columbia, Mo....	4-24-04	2.16	5	1218
La Crosse, Wis...	8- 4-05	2.14	5	1223
Topeka, Kans.....	7-31-02	2.12	7	1230
Cincinnati, O.....	7-21-03	2.12	1	1231
Chicago, Ill......	7- 9-03	2.12	2	1233
Louisville, Ky....	6-15-02	2.12	2	1235
Yankton, S. D...	9-20-02	2.08	3	1238
St. Paul, Minn...	10- 3-00	2.08	2	1240
Huron, S. D.....	8-18-04	2.07	2	1242
Oklahoma City Okla.	5- 6-00	2.05	4	1246
Cairo, Ill.........	7-30-01	2.04	3	1249
Dodge City, Kans.	7-28-00	2.02	3	1252
Oklahoma City Okla.	8-12-01	2.00	4	1256
Springfield, Ill....	8- 3-05	2.00	6	1262
Springfield, Mo...	8- 7-06	2.00	10	1272
Columbia, Mo....	6- 7-98	1.98	5	1277
Indianapolis, Ind..	6- 4-06	1.97	2	1279
Ft. Worth, Tex..	9-21-00	1.96	3	1282
St. Paul, Minn...	7-25-97	1.94	2	1284
Little Rock, Ark..	7-29-03	1.94	3	1287
Topeka, Kans.....	8- 4-06	1.93	7	1294
Omaha, Neb......	8-26-03	1.92	5	1299
Kansas City, Mo..	7- 5-04	1.92	7	1306
New Orleans, La..	11- 9-98	1.90	1	1307
Oklahoma City Okla.	5-21-03	1.90	4	1311
Milwaukee, Wis...	6-12-99	1.90	2	1313
Ft. Worth, Tex...	5-24-07	1.86	3	1316
Huron, S. D.....	8- 4-00	1.85	2	1318
Des Moines, Ia...	5-21-03	1.84	5	1323
Ft. Smith, Ark...	9- 2-06	1.82	7	1330
Nashville, Tenn...	9-14-01	1.80	2	1332
Dodge City, Kans.	8- 6-03	1.80	3	1335
Hannibal, Mo.....	7- 7-98	1.76	5	1340
New Orleans, La..	10- 7-00	1.76	1	1341
Lincoln, Neb......	5-10-05	1.76	6	1347
Dodge City, Kans.	5-13-98	1.72	3	1350
Columbus, O.....	8-15-00	1.72	1	1351
Hannibal, Mo.....	8-10-99	1.64	5	1356
New Orleans, La..	7- 5-02	1.63	1	1357
Louisville, Ky....	3-16-98	1.60	2	1359
Huron, S. D.....	5- 9-05	1.58	2	1361

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Lincoln, Neb.	5-24-03	1.55	6	1367
Oklahoma City Okla.	7-20-97	1.44	4	1371
Little Rock, Ark.	12-31-01	1.44	3	1374
New Orleans, La.	4-25-07	1.26	1	1375
Lincoln, Neb.	9-16-06	1.10	6	1381

Table V.

HEAVY PRECIPITATIONS.

10 MINUTES.

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Huron, S. D.	6-14-01	7.34	2	2
New Orleans, La.	9-30-05	7.06	1	3
Kansas City, Mo.	8-23-06	6.78	7	10
New Orleans, La.	5-30-07	6.50	1	11
Des Moines, Ia.	7-19-04	6.12	5	16
St. Louis, Mo.	7- 8-98	6.03	4	20
Springfield, Mo.	5-31-06	6.01	10	30
New Orleans, La.	8-25-04	5.93	1	31
Indianapolis, Ind.	9-30-02	5.84	2	33
Milwaukee, Wis.	6-24-04	5.78	2	35
Hannibal, Mo.	8-17-06	5.64	5	40
Columbia, Mo.	7- 2-05	5.62	5	45
Cincinnati, O.	5-20-02	5.61	1	46
Wichita, Kans.	9-17-05	5.50	10	56
Omaha, Neb.	7- 6-98	5.46	5	61
Columbus, O.	6-23-01	5.39	1	62
Louisville, Ky.	5-31-03	5.36	2	64
St. Paul, Minn.	8- 9-02	5.30	2	66
Memphis, Tenn.	3- 9-01	5.28	3	69
Hannibal, Mo.	5-26-06	5.23	5	74
Nashville, Tenn.	11-20-00	5.22	2	76
Milwaukee, Wis.	9-17-07	5.20	2	78
Denver, Colo.	5-27-98	5.02	1	79
Columbia, Mo.	6-25-99	5.02	5	84
Hannibal, Mo.	9- 4-98	4.97	5	89
Indianapolis, Ind.	8- 9-99	4.96	2	91
St. Louis, Mo.	6-13-00	4.94	4	95
Ft. Worth, Tex.	9-21-00	4.90	3	98
Davenport, Ia.	8-26-07	4.89	7	105
Lincoln, Neb.	8-15-00	4.82	6	111
Huron, S. D.	7- 6-05	4.80	2	113
New Orleans, La.	7-15-01	4.80	1	114
Chicago, Ill.	8- 5-05	4.76	2	116
Cairo, Ill.	6-28-05	4.74	3	119
Davenport, Ia.	6- 9-05	4.72	7	126
Ft. Worth, Tex.	3-25-04	4.72	3	129
Ft. Worth, Tex.	7- 2-05	4.70	3	132
Des Moines, Ia.	7-19-05	4.67	5	137
Columbia, Mo.	8-22-05	4.64	5	142
New Orleans, La.	3-17-04	4.62	1	143
Nashville, Tenn.	6-15-97	4.61	2	145
Des Moines, Ia.	5-28-00	4.60	5	150
Columbus, O.	7-11-97	4.57	1	151
New Orleans, La.	7-18-01	4.57	1	152
Evansville, Ind.	8- 5-03	4.56	4	156
Chicago, Ill.	7-15-06	4.53	2	161
Ft. Worth, Tex.	6- 3-04	4.52	3	159
Nashville, Tenn.	8-21-02	4.52	2	171
Hannibal, Mo.	9- 9-03	4.51	5	166
Dodge City, Kans.	8- 6-98	4.50	3	169
New Orleans, La.	4-17-01	4.50	1	172
La Crosse, Wis.	7- 9-03	4.50	5	177
Columbia, Mo.	5-31-02	4.49	5	182
Nashville, Tenn.	7-10-97	4.48	2	184
Columbia, Mo.	8-25-00	4.46	5	189
Nashville, Tenn.	6-28-00	4.45	2	191
St. Louis, Mo.	8- 6-07	4.44	4	195
Columbia, Mo.	9-16-05	4.42	5	200
Little Rock, Ark.	7-11-03	4.42	3	203
Dodge City, Kans.	6-17-06	4.42	3	206
New Orleans, La.	12-22-07	4.41	1	207
Davenport, Ia.	7-10-07	4.40	7	214
Little Rock, Ark.	5-21-98	4.38	3	217
New Orleans, La.	8-25-03	4.38	1	218
St. Louis, Mo.	5- 1-99	4.38	4	222
Springfield, Mo.	7-26-05	4.38	10	232
Nashville, Tenn.	7-19-04	4.37	2	234
Yankton, S. D.	7-15-00	4.36	3	237
Yankton, S. D.	8-18-99	4.35	3	240
Wichita, Kans.	7- 6-04	4.35	10	250
Louisville, Ky.	8- 8-98	4.35	2	252
New Orleans, La.	7- 6-04	4.31	1	253
Lincoln, Neb.	7-31-03	4.31	6	259
Nashville, Tenn.	6-15-05	4.30	2	261
Kansas City, Mo.	6-22-06	4.30	7	268
Lincoln, Neb.	7-15-00	4.28	6	274
New Orleans, La.	3-30-99	4.27	1	275
St. Louis, Mo.	5- 4-02	4.26	4	279
Lincoln, Neb.	8-17-97	4.26	6	285
Topeka, Kans.	9-13-01	4.24	7	292
Hannibal, Mo.	8-13-04	4.24	5	297
Ft. Worth, Tex.	7-28-06	4.22	3	300
Dodge City, Kans.	6- 4-98	4.22	3	303
Oklahoma City Okla.	6- 4-04	4.18	4	307
New Orleans, La.	6-22-03	4.18	1	308
Little Rock, Ark.	5- 8-00	4.16	3	311
Ft. Worth, Tex.	6-20-06	4.16	3	314
Little Rock, Ark.	5-12-05	4.14	3	317
Lexington, Ky.	7-28-04	4.14	1	318
Ft. Worth, Tex.	6- 5-07	4.14	3	321
New Orleans, La.	4-25-07	4.14	1	322
Indianapolis, Ind.	7-25-97	4.13	2	324
Topeka, Kans.	7-21-04	4.13	7	331
Indianapolis, Ind.	8-19-01	4.12	2	333
New Orleans, La.	7-19-01	4.08	1	334
Valentine, Neb.	8- 2-04	4.08	3	337
Cairo, Ill.	6-13-99	4.06	3	340
Cincinnati, O.	7-22-06	4.05	1	341
Evansville, Ind.	7-11-04	4.04	4	345
Evansville, Ind.	5- 8-00	4.02	4	349
Topeka, Kans.	8- 2-03	4.02	7	356
New Orleans, La.	4-25-07	3.99	1	357
Shreveport, La.	6- 1-06	3.98	1	358
Bismarck, N. D.	6-13-01	3.98	1	359
New Orleans, La.	7-10-07	3.97	1	360
Davenport, Ia.	9-25-04	3.96	7	367
Topeka, Kans.	6-24-03	3.96	7	374
Ft. Worth, Tex.	5- 2-06	3.94	3	377
Huron, S. D.	8- 8-04	3.93	2	379
New Orleans, La.	8- 5-07	3.92	1	380
St. Paul, Minn.	8- 5-98	3.92	2	382
Des Moines, Ia.	7-14-07	3.92	5	387
Oklahoma City Okla.	5- 6-00	3.92	4	391
Nashville, Tenn.	6- 7-00	3.91	2	393
Columbia, Mo.	6-14-98	3.90	5	398
Topeka, Kans.	9-22-02	3.90	7	405
Dodge City, Kans.	6- 7-99	3.90	3	408
Columbus, O.	6-14-04	3.89	1	409
Little Rock, Ark.	9-15-98	3.88	3	412
Dodge City, Kans.	8-18-04	3.88	3	415
Dodge City, Kans.	6- 7-99	3.88	3	418
Wichita, Kans.	8- 1-03	3.88	10	428
New Orleans, La.	3-14-03	3.88	1	429
Cincinnati, O.	5-29-99	3.87	1	430

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Shreveport, La....	7-23-05	3.86	4	434
Memphis, Tenn....	6- 7-05	3.86	3	437
Cairo, Ill.........	8- 7-06	3.86	3	440
Indianapolis, Ind..	8-12-00	3.85	2	442
New Orleans, La..	6-20-00	3.84	1	443
St. Louis, Mo....	7-24-00	3.84	4	447
Springfield, Ill....	8- 7-07	3.83	6	453
Huron, S. D.....	7-20-07	3.83	2	455
Chicago, Ill.......	7-28-06	3.82	2	457
Oklahoma City Okla.	5- 6-99	3.81	4	461
St. Paul, Minn...	6-28-01	3.80	2	463
St. Paul, Minn...	9- 5-04	3.80	2	465
New Orleans, La..	4-17-00	3.80	1	466
Dodge City, Kans.	7-23-99	3.78	3	469
St. Louis, Mo....	7- 4-99	3.78	4	473
Lexington, Ky....	8-23-05	3.78	1	474
New Orleans, La..	7-11-07	3.77	1	475
Wichita, Kans....	6- 2-04	3.76	10	485
Kansas City, Mo..	9- 5-98	3.76	7	492
Davenport, Ia.....	9- 1-05	3.75	7	499
Oklahoma City Okla.	8-28-00	3.75	4	503
Davenport, Ia.....	9-14-03	3.74	7	510
Lexington, Ky....	8-22-00	3.72	1	511
Columbia, Mo.....	10-16-05	3.72	5	516
New Orleans, La..	7-11-04	3.70	1	517
Columbia, Mo....	7-31-99	3.69	5	522
Ft. Worth, Tex..	5-11-05	3.68	3	523
Kansas City, Mo..	8- 2-05	3.67	7	530
Hannibal, Mo.....	9-25-98	3.67	5	535
Wichita, Kans.....	7-14-04	3.66	10	545
Kansas City, Mo..	9-14-05	3.66	7	552
Yankton, S. D....	7- 8-98	3.66	3	555
New Orleans, La..	3-14-03	3.66	1	556
Wichita, Kans.....	6-15-05	3.64	10	566
New Orleans, La..	8-12-06	3.63	1	567
New Orleans, La..	8-22-03	3.62	1	568
Valentine, Neb...	7-21-04	3.62	3	571
St. Paul, Minn...	6-14-01	3.62	2	573
Yankton, S. D....	5-24-06	3.62	3	576
Topeka, Kans.....	8-26-02	3.61	7	583
Lincoln, Neb.....	4-23-97	3.60	6	589

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Indianapolis, Ind..	7- 6-04	3.60	2	591
Oklahoma City Okla.	5-29-05	3.60	4	595
Denver, Colo.....	9-20-02	3.60	1	596
Ft. Smith, Ark...	8-26-04	3.58	7	603
Des Moines, Ia...	7-16-07	3.57	5	608
Dodge City, Kans.	7-21-07	3.56	3	611
Shreveport, La....	6-27-02	3.56	4	615
La Crosse, Wis...	7-21-07	3.56	5	620
Little Rock, Ark..	11-28-05	3.56	3	623
Columbia, Mo.....	9-18-04	3.54	5	628
Evansville, Ind...	9- 2-00	3.54	4	632
New Orleans, La..	6-27-04	3.54	1	633
Milwaukee, Wis...	9- 2-00	3.54	2	635
New Orleans, La..	3-14-03	3.54	1	636
Indianapolis, Ind..	3-31-04	3.53	2	638
Shreveport, La....	4- 2-05	3.53	4	642
St. Paul, Minn...	8- 4-05	3.52	2	644
Omaha, Neb......	7-18-07	3.52	5	649
Wichita, Kans....	6- 2-05	3.52	10	659
Wichita, Kans....	8-16-07	3.50	10	669
Wichita, Kans....	5-20-03	3.50	10	679
Kansas City, Mo..	8-21-04	3.50	7	686
Oklahoma City Okla.	5- 5-99	3.50	4	690
Bismarck, N. D..	6- 4-05	3.50	1	691
Dubuque, Ia......	8-15-07	3.50	5	696
Indianapolis, Ind..	8-19-06	3.49	2	698
Kansas City, Mo..	5-24-05	3.48	7	705
Cincinnati, O.....	7- 5-97	3.46	1	706
Columbus, O.......	7-28-02	3.46	1	707
Oklahoma City Okla.	9-11-06	3.46	4	711
Nashville, Tenn...	9- 4-06	3.45	2	713
Hannibal, Mo.....	7- 7-98	3.44	5	718
Indianapolis, Ind..	8- 2-99	3.44	2	720
Nashville, Tenn...	9- 1-00	3.44	2	722
Evansville, Ind...	6- 2-04	3.44	4	726
Huron, S. D.....	8- 8-01	3.44	2	728
Dodge City, Kans.	8-16-07	3.44	3	731
Yankton, S. D...	7-14-00	3.43	3	734
Lincoln, Neb......	8- 4-02	3.42	6	740
Omaha, Neb......	6-26-06	3.42	5	745

(745 weighted rains every 2 years.)

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Springfield, Mo...	8-14-05	3.42	10	755
St. Paul, Minn...	9-25-06	3.42	2	757
New Orleans, La..	8-24-03	3.42	1	758
Chicago, Ill.......	5-11-05	3.42	2	760
Huron, S. D.....	6-27-05	3.41	2	762
Ft. Worth, Tex...	5- 3-04	3.40	3	765
Milwaukee, Wis...	8-23-98	3.39	2	767
Ft. Smith, Ark...	6-30-07	3.39	7	774
Springfield, Mo...	7-19-06	3.38	10	784
Memphis, Tenn...	8- 9-05	3.38	3	787
St. Louis, Mo....	5-31-03	3.37	4	791
Kansas City, Mo..	3-24-04	3.36	7	798
New Orleans, La..	8-22-03	3.35	1	799
Lexington, Ky....	5-10-05	3.35	1	800
Memphis, Tenn....	11-19-06	3.34	3	803
Yankton, S. D...	8-23-06	3.34	3	806
Evansville, Ind...	7-20-04	3.34	4	810
Shreveport, La....	5-21-05	3.33	4	814
New Orleans, La..	9-16-01	3.33	1	815
Bismarck, N. D..	10- 1-98	3.33	1	816
Huron, S. D....	6-24-02	3.33	2	818
Louisville, Ky....	7-10-97	3.32	2	820
Des Moines, Ia..	4-22-97	3.32	5	825
Shreveport, La....	5- 7-07	3.31	4	829
Cincinnati, O......	8- 3-00	3.30	1	830
Dodge City, Kan.	7-19-97	3.30	3	833
Huron, S. D.....	6-12-00	3.30	2	835

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Oklahoma City Okla.	8- 7-06	3.28	4	839
Shreveport, La....	5- 3-06	3.28	4	843
Chicago, Ill.......	7- 1-01	3.28	2	845
Shreveport, La....	7-23-02	3.27	4	852
Valentine, Neb...	7-11-06	3.26	3	848
Kansas City, Mo..	5-23-02	3.26	7	859
Nashville, Tenn...	7-11-97	3.25	2	861
Topeka, Kans.....	7-28-01	3.24	7	868
Little Rock, Ark..	8-25-99	3.24	3	871
Evansville, Ind...	8-14-06	3.22	4	875
Little Rock, Ark..	7-29-00	3.22	3	878
St. Paul, Minn...	10- 3-03	3.22	2	880
New Orleans, La..	6- 4-05	3.22	1	881
St. Louis, Mo....	5- 5-00	3.21	4	885
Yankton, S. D...	7-10-07	3.20	3	888
Kansas City, Mo..	7-19-06	3.20	7	895
Kansas City, Mo..	9- 6-05	3.20	7	902
Nashville, Tenn...	6-27-04	3.18	2	904
Little Rock, Ark..	4-24-05	3.18	3	907
Springfield, Mo...	6- 4-04	3.18	10	917
Columbia, Mo.....	10-28-00	3.18	5	922
Columbus, O.....	7-19-00	3.17	1	923
Lexington, Ky....	7-19-02	3.16	1	924
St. Louis, Mo....	5-21-98	3.15	4	928
Valentine, Neb...	7- 9-07	3.14	3	931
Little Rock, Ark..	6-22-04	3.14	3	934

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
Nashville, Tenn.	6- 9-03	3.13	2	936
New Orleans, La.	6- 7-04	3.12	1	937
Memphis, Tenn.	7-16-06	3.12	3	940
Oklahoma City Okla.	5-28-03	3.12	4	944
Columbia, Mo.	5-25-03	3.12	5	949
Kansas City, Mo.	6-22-01	3.12	7	956
Des Moines, Ia.	4-17-00	3.12	5	961
Columbus, O.	7-20-97	3.10	1	962
Oklahoma City Okla.	3-25-02	3.10	4	966
Springfield, Mo.	6-24-06	3.10	10	976
Lincoln, Neb.	8- 4-07	3.10	6	982
Columbia, Mo.	4-25-02	3.09	5	987
Huron, S. D.	6-17-04	3.08	2	989
New Orleans, La.	11-22-01	3.08	1	990
Dodge City, Kans.	10- 9-98	3.08	3	993
New Orleans, La.	7-11-06	3.07	1	994
Valentine, Neb.	7- 6-07	3.06	3	997
Wichita, Kans.	10-30-03	3.04	10	1007
New Orleans, La.	11- 9-98	3.02	1	1008
Columbia, Mo.	4-24-04	3.02	5	1013
New Orleans, La.	8- 3-02	3.01	1	1014
Lincoln, Neb.	5-28-05	3.00	6	1020
Kansas City, Mo.	8-15-03	3.00	7	1027
Oklahoma City Okla.	5-23-03	3.00	4	1031
Springfield, Ill.	5- 5-01	3.00	6	1037
Denver, Colo.	6- 2-00	3.00	1	1038
Evansville, Ind.	9- 2-04	3.00	4	1042
Ft. Worth, Tex.	6-24-03	3.00	3	1045
Memphis, Tenn.	6-23-99	2.99	3	1048
Evansville, Ind.	7-10-05	2.98	4	1052
Yankton, S. D.	9-20-02	2.98	3	1055
Hannibal, Mo.	7- 4-99	2.98	5	1060
Des Moines, Ia.	7-18-04	2.97	5	1065
Topeka, Kans.	7-31-02	2.87	7	1072
Ft. Worth, Tex.	9-21-00	2.96	3	1075
Kansas City, Mo.	7-14-07	2.96	7	1082
New Orleans, La.	8- 3-98	2.95	1	1083
Hannibal, Mo.	8- 8-99	2.93	5	1088
Omaha, Neb.	7-15-00	2.92	5	1093
Kansas City, Mo.	9- 9-03	2.92	7	1100
Memphis, Tenn.	8-30-97	2.92	3	1103
Cairo, Ill.	6- 7-00	2.92	3	1106
Bismarck, N. D.	6-16-97	2.92	1	1107
New Orleans, La.	7-25-99	2.92	1	1108
New Orleans, La.	7- 7-98	2.90	1	1109
New Orleans, La.	8- 5-98	2.90	1	1110
Indianapolis, Ind.	5-29-00	2.90	2	1112
Louisville, Ky.	3-16-98	2.90	2	1114
Chicago, Ill.	7- 9-03	2.90	2	1116
Evansville, Ind.	5-30-00	2.90	4	1120
St. Paul, Minn.	10- 3-00	2.90	2	1122
Memphis, Tenn.	8-18-01	2.88	3	1125
Chicago, Ill.	5-24-02	2.87	2	1127
New Orleans, La.	7-18-00	2.86	1	1128
Hannibal, Mo.	8- 8-99	2.86	1	1129
Cincinnati, O.	7-21-03	2.85	1	1130
Kansas City, Mo.	7- 2-05	2.84	7	1137
Louisville, Ky.	6-15-02	2.83	2	1139
Ft. Worth, Tex.	10-21-00	2.82	3	1142
Springfield, Ill.	6- 1-02	2.82	6	1148
New Orleans, La.	7-17-97	2.81	1	1149
Lincoln, Neb.	7-22-02	2.80	6	1155
Lincoln, Neb.	5-10-05	2.80	6	1161
Little Rock, Ark.	6- 1-98	2.80	3	1164

City.	Date.	Av. Rate per hr.	Final Wt.	Partial Tls.
New Orleans, La.	10- 7-00	2.80	1	1165
New Orleans, La.	5-23-07	2.80	1	1166
Columbia, Mo.	10- 6-00	2.78	5	1171
St. Louis, Mo.	7-29-03	2.78	4	1175
St. Paul, Minn.	7-30-04	2.78	2	1177
Milwaukee, Wis.	7-21-07	2.76	2	1179
Ft. Worth, Tex.	5-24-07	2.74	3	1182
Yankton, S. D.	9-20-02	2.73	3	1185
Hannibal, Mo.	6- 4-04	2.73	5	1190
Milwaukee, Wis.	9-14-03	2.72	2	1192
Dodge City, Kans.	7-28-00	2.72	3	1195
New Orleans, La.	7- 4-03	2.72	1	1196
Dubuque, Ia.	9-25-04	2.72	5	1201
Davenport, Ia.	9- 9-03	2.70	7	1208
La Crosse, Wis.	8- 4-05	2.70	5	1213
St. Paul, Minn.	8-18-07	2.70	2	1215
St. Paul, Minn.	7-25-97	2.70	2	1217
Little Rock, Ark.	7-29-03	2.68	3	1220
Valentine, Neb.	6-27-05	2.68	3	1223
Oklahoma City Okla.	5-21-03	2.68	4	1227
Dodge City, Kans.	8- 6-03	2.66	3	1238
Memphis, Tenn.	5-26-02	2.64	3	1230
Omaha, Neb.	8-26-03	2.63	5	1235
Huron, S. D.	8-18-04	2.63	2	1240
New Orleans, La.	3-19-05	2.63	1	1241
Nashville, Tenn.	9-14-01	2.61	2	1243
Lincoln, Neb.	9-14-06	2.61	6	1249
Lincoln, Neb.	8- 7-07	2.60	6	1255
Omaha, Neb.	6-16-00	2.60	5	1260
Springfield, Mo.	8- 7-06	2.60	10	1270
Cairo, Ill.	7-30-01	2.60	3	1273
Cairo, Ill.	6-22-97	2.58	3	1276
Evansville, Ind.	5-31-07	2.58	4	1280
Des Moines, Ia.	5-21-03	2.56	5	1285
Milwaukee, Wis.	6-12-99	2.55	2	1287
St. Paul, Minn.	6-12-99	2.54	2	1289
Indianapolis, Ind.	6- 4-06	2.54	2	1291
Oklahoma City Okla.	8-11-02	2.52	4	1295
Topeka, Kans.	8- 4-06	2.52	7	1302
Huron, S. D.	8- 4-00	2.51	2	1304
Springfield, Ill.	8- 3-05	2.50	6	1310
Columbia, Mo.	7-18-02	2.50	5	1315
Dodge City, Kan.	5-13-98	2.46	3	1318
Little Rock, Ark.	9-10-99	2.44	3	1321
Memphis, Tenn.	3-26-02	2.44	3	1324
New Orleans, La.	9- 9-98	2.43	1	1325
Huron, S. D.	5- 9-05	2.41	2	1327
Ft. Worth, Tex.	8-11-06	2.40	3	1330
Oklahoma City Okla.	8-12-01	2.38	4	1334
Ft. Smith, Ark.	9- 2-06	2.38	7	1341
Columbus, O.	8-15-00	2.31	1	1342
New Orleans, La.	7- 5-02	2.30	1	1343
Kansas City, Mo.	7- 5-04	2.22	7	1350
Oklahoma City Okla.	7-20-97	2.16	4	1354
Little Rock, Ark.	12-13-01	2.10	3	1357
Kansas City, Mo.	7- 7-02	1.94	7	1364
Des Moines, Ia.	7-23-00	1.90	5	1369
New Orleans, La.	4-25-07	1.90	1	1370
Lincoln, Neb.	5-24-03	1.81	6	1376
Lincoln, Neb.	9-16-06	1.79	6	1382
Hannibal, Mo.	8-10-99	1.73	5	1387
Columbia, Mo.	6- 7-98	1.66	5	1392

Table VI.

Cities.	Years considered.	Years of record.	Dist. wght.	Final wght.
Kansas City, Mo.	10	10	7	7
Topeka, Kans.	10	8½	6	7
Wichita, Kans.	10	5	5	10
Lincoln, Neb.	10	11	5	6
Omaha, Neb.	10	11	5	5
Des Moines, Ia.	10	11	5	6
Hannibal, Mo.	10	9½	5	5
Columbia, Mo.	10	10	5	5
Springfield, Mo.	10	5	5	10
Oklahoma City Okla.	10	10½	4	4
Davenport, Ia.	10	6	4	7

Cities.	Years considered.	Years of record.	Dist. wght.	Final wght.
Springfield, Ill....	10	6½	4	6
St. Louis, Mo....	10	11	4	4
Ft. Smith, Ark..	10	6	4	7
Dodge City, Kans.	10	11	3	3
Yankton, S. D...	10	10½	3	3
La Crosse, Wis...	10	6	3	5
Dubuque, Ia......	10	5½	3	5
Evansville, Ind...	10	8	3	4
Cairo, Ill.........	10	10½	3	3
Memphis, Tenn...	10	11	3	3
Little Rock, Ark..	10	11	3	3
Ft. Worth, Tex...	10	7½	2	3
Valentine, Neb....	10	6	2	3
Huron, S. D.....	10	10	2	2
St. Paul, Minn..	10	11	2	2
Milwaukee, Wis...	10	11	2	2
Chicago, Ill.......	10	11	2	2
Indianapolis, Ind..	10	11	2	2
Louisville, Ky....	10	11	2	2
Nashville, Tenn....	10	11	2	2
Shreveport, La....	10	5½	2	4
Pueblo, Colo......	10	8	1	1
Denver, Colo.....	10	11	1	1
Bismarck, N. D..	10	11	1	1
Columbus, O......	10	10½	1	1
Cincinnati, O.....	10	11	1	1
Lexington, Ky....	10	9	1	1
New Orleans, La..	10	11	1	1

Total final weight................149
Twice the final weight............298
Five times the final weight.......745

Table VII. Precipitations Used in Determining Form of 40 Min. Typical Rain Curve, Giving Depth in Inches for Each 5 Minutes.

Five Minute Intervals.

From Beginning of the Downpour.

Cities—	Date															
Evansville, Ind.	9- 2-00	.08	.09	.09	.17	.26	.32	.28	.21	.15	.21	.20	.14			
Lexington, Ky.	8-22-00	.22	.21	.25	28	.36	.21	.13	.15	.05	.10	.04	.01			
Columbia, Mo.	8-22-05	.04	.08	.06	.20	.34	.42	.36	.24	.12	.06	.03	.07			
Shreveport, La.	6- 1-06	.08	.20	.31	.39	.17	.22	.20	.16	.11	.10	.05	.01			
New Orleans, La.	3-14-03	.07	.32	.35	.25	.17	.13	.10	.29	.07	.24	.22	.32	.29	.16	.08
Springfield, Mo.	7-26-05	.07	.14	.20	.32	.43	.26	.34	.17	.06	.08	.12	.22	.12	.10	.04

Table VIII. The Same as the Above, Except that the Arrangement is Symmetrical, as Shown in Fig. 5.

Five Minute Intervals.

Cities—	No.																		
Evansville	1			.08	.09	.09	17	.26	.32	.28	.21	.15	.21	.20	.14				
Lexington	2				.22	.21	.25	.28	.36	.21	.13	.15	.05	.10	.04	.01			
Columbia	3			.04	.08	.06	.20	.34	.42	.36	.24	.12	.06	.03	.07				
Shreveport	4					.08	.20	.31	.39	.17	.22	.20	.16	.11	.10	.05	.01		
New Orleans	5	.07	.32	.35	.25	.17	.13	.10	.29	.07	.24	.22	.32	.29	.16	.08			
Springfield	6				.07	.14	.20	.32	.43	.26	.34	.17	.06	.08	.12	.22	.12	.10	.04

Table IX. Showing Method of Obtaining Typical Intensities. The Data is that of Table VII Multiplied by the Weights Given.

No.	Weight.	Weighted Five Minute Intervals.																	
1	4			.32	.36	.36	.68	1.04	1.28	1.12	.84	.60	.84	.80	.56				
2	1				.22	.21	.25	.28	.36	.21	.13	.15	.05	.10	.04	.01			
3	5			.20	.40	.30	1.00	1.70	2.10	1.80	1.20	.75	.25	.15	.35	.05			
4	4					.32	.80	1.24	1.56	.68	.88	.80	.64	.44	.40	.20	.04		
5	1	.07	.32	.35	.25	.17	.13	.10	.29	.07	.24	.22	.32	.29	.16	.08			
6	5				.35	.70	1.00	1.60	2.15	1.30	1.70	.85	.30	.40	.60	1.10	.60	.50	.20
Total	20	.07	.32	.87	1.58	2.06	3.86	5.96	7.74	5.18	4.99	3.37	2.40	2.18	2.11	1.44	.64	.50	.20
Average		.00	.01	.04	.08	.10	.19	.30	.39	.26	.25	.17	.12	.11	.11	.07	.03	.03	.01
Hourly rate		.00	.12	.48	.96	1.20	2.28	3.60	4.68	3.12	3.00	2.04	1.44	1.32	1.32	.84	.36	.36	.12